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Woods Hole Oceanographic Institution

WHOI Hawaii Ocean Timeseries Station (WHOTS):

WHOTS-6 2009 Mooring Turnaround Cruise Report

by

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Abstract

The Woods Hole Oceanographic Institution (WHOI) Hawaii Ocean Timeseries Site (WHOTS), 100 km north of Oahu, Hawaii, is intended to provide long-term, high-quality air-sea fluxes as a part of the NOAA Climate Observation Program. The WHOTS mooring also serves as a coordinated part of the Hawaiian Ocean Timeseries (HOT) program, contributing to the goals of observing heat, fresh water and chemical fluxes at a site representative of the oligotrophic North Pacific Ocean. The approach is to maintain a surface mooring outfitted for meteorological and oceanographic measurements at a site near 22.75°N, 158°W by successive mooring turnarounds. These observations will be used to investigate air–sea interaction processes related to climate variability.

The first WHOTS mooring (WHOTS-1) was deployed in August 2004. Turnaround cruises for successive moorings (WHOTS-2 through WHOTS-5) have typically been in either June or July. This report documents recovery of the WHOTS-5 mooring and deployment of the sixth mooring (WHOTS-6). The moorings utilize Surlyn foam buoys as the surface element and are outfitted with two Air–Sea Interaction Meteorology (ASIMET) systems. Each ASIMET system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum. The upper 155 m of the mooring is outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity in a cooperative effort with R. Lukas of the University of Hawaii (UH). A pCO2 system is installed on the buoy in a cooperative effort with Chris Sabine at the Pacific Marine Environmental Laboratory. Dr. Frank Bradley, CSIRO, Australia, assisted with meteorological sensor comparisons. A NOAA “Teacher at Sea” and a NOAA “Teacher in the Lab” participated in the cruise.

The WHOTS mooring turnaround was done on the University of Hawaii research vessel *Kilo Moana*, Cruise KM-09-16, by the Upper Ocean Processes Group of the Woods Hole Oceanographic Institution in cooperation with UH and NOAA’s Earth System Research Laboratory, Physical Sciences Division (ESRL/PSD). The cruise took place between 9 and 17 July 2009. Operations began with deployment of the WHOTS-6 mooring on 10 July at approximately 22°40.0′N, 157°57.0′W in 4758 m of water. This was followed by meteorological intercomparisons and CTDs at the WHOTS-6 and WHOTS-5 sites. The WHOTS-5 mooring was recovered on 15 July 2009. The *Kilo Moana* then moved to the HOT central site (22°45.0′N, 158°00.0′W) for CTD casts. This report describes the cruise operations in more detail, as well as some of the in-port operations and pre-cruise buoy preparations.

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1. Introduction

The Hawaii Ocean Timeseries (HOT) site, 100 km north of Oahu, Hawaii, has been occupied since 1988 as a part of the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS). The present HOT program includes comprehensive, interdisciplinary upper ocean observations, but does not include continuous surface forcing measurements. Thus, a primary driver for the WHOI HOT Site (WHOTS) mooring is to provide long-term, high-quality air-sea fluxes as a coordinated part of the HOT program and to contribute to the program goals of observing heat, fresh water and chemical fluxes at a site representative of the oligotrophic North Pacific Ocean. The WHOTS mooring also serves as an Ocean Reference Station – a part of NOAA's Ocean Observing System for Climate – providing time-series of accurate surface meteorology, air-sea fluxes, and upper ocean variability to quantify air-sea exchanges of heat, freshwater, and momentum, to describe the local oceanic response to atmospheric forcing, to motivate and guide improvement to atmospheric, oceanic, and coupled models, to calibrate and guide improvement to remote sensing products, and to provide anchor point for the development of new, basin scale air-sea flux fields.

To accomplish these objectives, a surface mooring with sensors suitable for the determination of air–sea fluxes and upper ocean properties is being maintained at a site near 22°45′N, 158°00′W (Fig. 1-1) by means of annual "turnarounds" (recovery of one mooring and deployment of a new mooring near the same site). The moorings use Surlyn foam buoys as the surface element, outfitted with two Air–Sea Interaction Meteorology (ASIMET) systems. Each ASIMET system measures, records, and transmits via Argos satellite the surface meteorological variables necessary to compute air–sea fluxes of heat, moisture and momentum.

Subsurface observations have been made on all WHOTS deployments in cooperation with Roger Lukas at the University of Hawaii (UH). The upper 155 m of the mooring line is outfitted with oceanographic sensors for the measurement of temperature, conductivity and velocity. Starting with the WHOTS-4 deployment (Whelan et al., 2008), a pCO2 system for investigation of the air-sea exchange of CO2 at the ocean surface was mounted in the buoy well in cooperation with Chris Sabine at the Pacific Marine Environmental Laboratory (PMEL).

Personnel from NOAA's Earth System Research Laboratory, Physical Sciences Division (ESRL/PSD) participated in the WHOTS-6 cruise, operating meteorological sensors installed on their own mast at the port bow of the *Kilo Moana* and radiometers mounted on the port-side bridge wing. The ESRL/PSD group also launched radiosondes at 4 h intervals. The WHOI UOP Group installed an AutoIMET system on the ship's bridge mast as well as radiometers on the port bridge wing. Dr. Frank Bradley from CSIRO, Australia, participated in the cruise with the goal of detailed comparison among shipboard and buoy meteorological observations in support of our efforts to quantify the accuracy of the meteorological and surface flux observations made from the Ocean Reference Stations.

NOAA sponsored Scott Sperber as a NOAA Teacher-at-Sea and Diane Stanitsky as a Teacher in the Lab to participate on the cruise.

The mooring turnaround was done on the UH Research Vessel *Kilo Moana,* Cruise KM-09-16, by the Upper Ocean Processes Group (UOP) of the Woods Hole Oceanographic Institution (WHOI) with assistance from UH and ESRL/PSD. The cruise was completed using 8 ship days between 9 and 17 July 2009. The cruise originated from, and returned to, Honolulu, HI (Fig. 1-1). The facilities of the UH Marine Center at Sand Island, and a tent maintained by the Hawaii Undersea Research Lab, were used for pre-cruise staging.

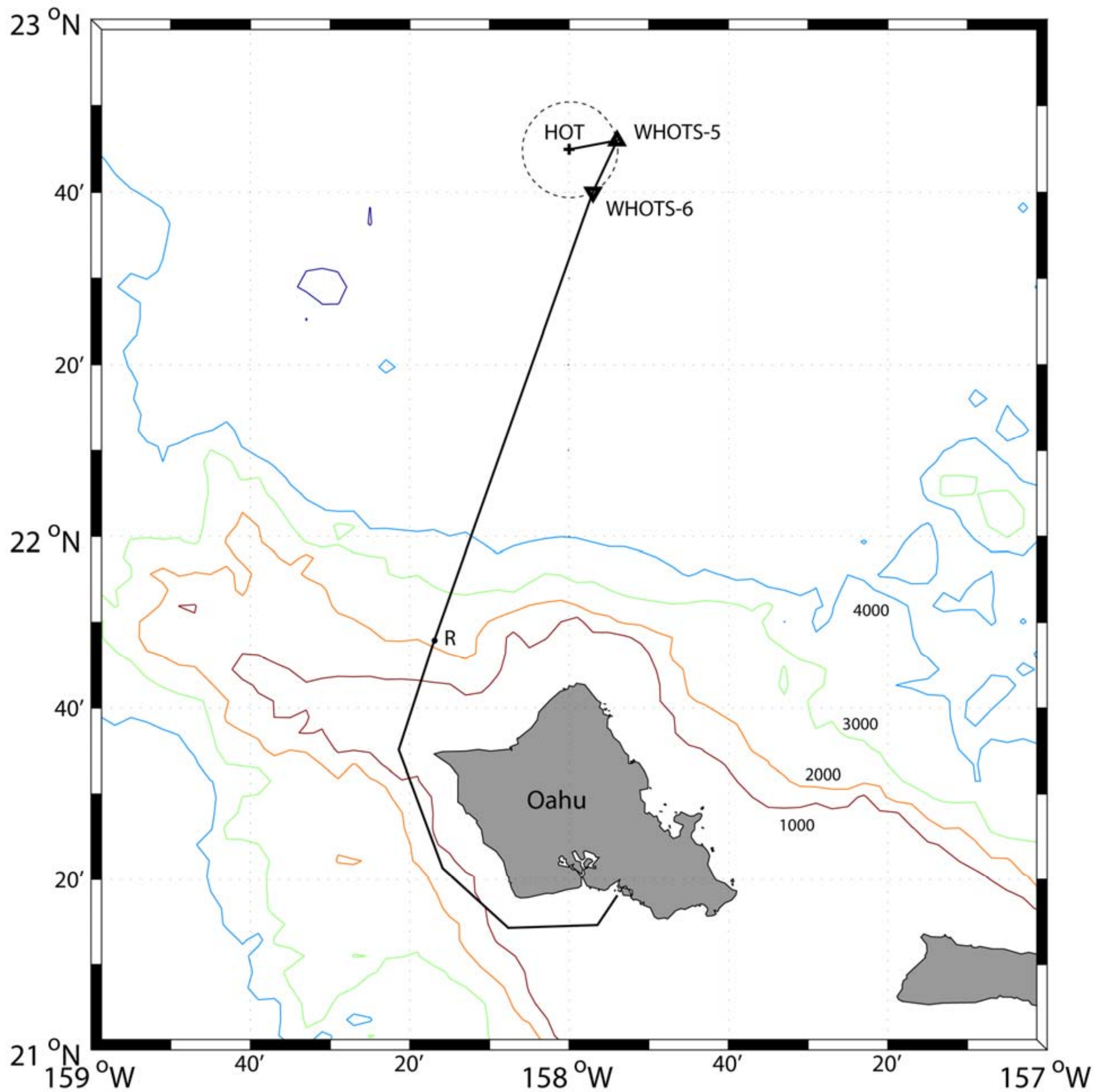

Figure 1-1. WHOTS-6 site map and outbound cruise track. The WHOTS moorings are at the perimeter of the Station Aloha circle (dashed) with the Hawaii Ocean Timeseries (HOT) site at its center. Release tests were done on the way to WHOTS-6 at the site marked R.

There were five principal operations during the cruise. First, the WHOTS-6 mooring was deployed. Second, an intercomparison was done between shipboard meteorological sensors and the WHOTS-6 buoy meteorological sensors with the *Kilo Moana* holding position about 0.2 nm downwind of the buoy. Third, an intercomparison was done between shipboard meteorological sensors and the WHOTS-5 buoy with the *Kilo Moana* holding position about 0.2 nm downwind. Shallow (200 – 500 m depth) CTDs were done during the WHOTS-6 and WHOTS-5 intercomparison periods. Fourth, the WHOTS-5 mooring was recovered. Finally, a full-depth CTD cast was done at the HOT central site.

2. Pre-Cruise Operations

a. Staging and Loading

Two 40’ containers were shipped from Woods Hole, MA, June 4th and arrived in Honolulu June 22nd. They were delivered to the University of Hawaii Marine Center (UHMC) on June 29th. Two WHOI technicians arrived at UHMC on July 2nd to unload and begin staging for the 2009 WHOTS cruise. The ship was loaded July 7th for sailing on the 9th.

Pre-cruise operations were conducted on the UHMC grounds. UH personnel assisted with in-port preparations. The UOP group was grateful for access to the Hawaii Undersea Research Laboratory (HURL) tent to house gear not suitable for outside storage and for use as a staging for electronics. In addition to loading the ship, pre-cruise operations included: assembly of primary and spare anchor, assembly of glass balls onto 4 m chain sections, painting of the buoy hull, assembly of the buoy tower top, insertion of the tower top assembly into the foam buoy hull, a buoy spin, evaluation of ASIMET data, and preparation of the oceanographic instruments.

Continuing pre-cruise work in Hawaii was planned, therefore a 20’ container was on site at the UH Marine Center. Not all recovered gear was shipped back to WHOI. Items left at the Marine Center included the assembled buoy hull, a spare anchor, approximately 80 glass balls, and spare wire, nylon, and colmega.

b. Buoy Spin

A buoy spin was begun by orienting the buoy tower section towards a distant point with a known (i.e. determined with a surveyor’s compass) magnetic heading. The buoy was then rotated, using a fork-truck, through eight positions in approximate 45-degree increments. At each position, the vanes of both wind sensors were oriented parallel with the sight line (vane towards the sighting point and propeller away) and held for 15 minutes. If the compass and vane were working properly, they co-varied such that their sum (the wind direction) was equal to the sighting direction at each position (expected variability is plus or minus 6 degrees).

The first buoy spins were done in the parking lot outside the WHOI Clark Laboratory high bay, with care taken to ensure that cars were not parked within about 30 ft of the buoy. The sighting angle to “the big tree” was about 310°, WHOI buoy spin.

The second buoy spin was done in Honolulu 7/8/02 2100 UTC (Fig. 2-1), on an open area of dirt near the pier. A surveyor’s compass was used to determine that the magnetic field in the

area was constant within a few degrees. A building with tall antennae on top was sighted approximately 3 miles and was used as a sighting point.

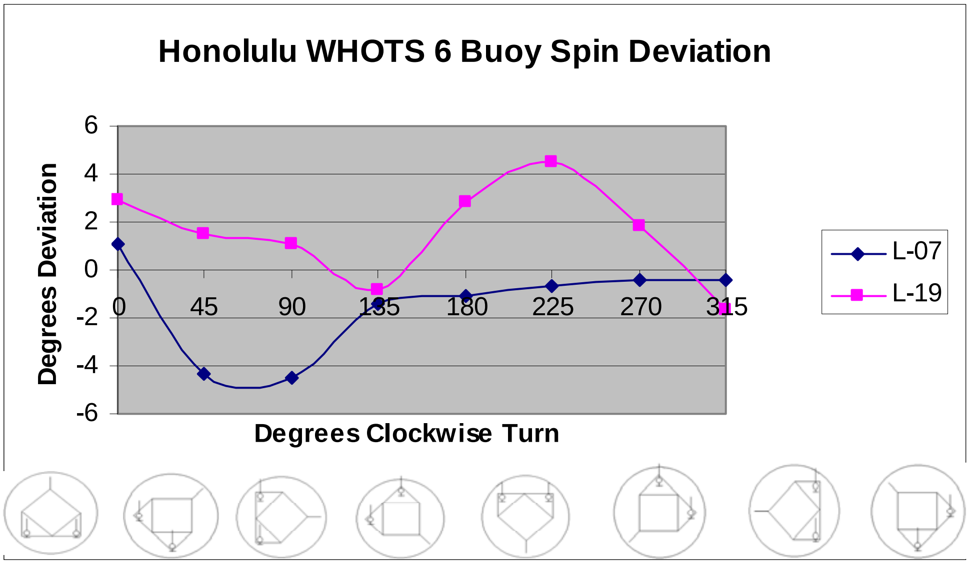

Figure 2-1: WHOTS 6 Buoy Spin

c. Sensor Evaluation

Once the buoy well and tower top were assembled, the ASIMET modules were initialized and connected to the loggers. When mechanical assembly was complete, power was applied, the loggers were started, and data acquisition began. Evaluation of the primary sensor suite was done through a series of overnight tests. Both hourly Argos transmissions and 1 min logger data were examined.

Examination of Argos data after setup of the buoy tower on 4 July (yearday 185) showed good performance for all modules except HRH, where a disagreement in AT of roughly 1.0°C during the day and greater than 2.0°C at night was observed (Fig. 2-2). It appeared that HRH SN 208 (L07) was reading low compared to HRH 219 (L19). At 1930 UTC, HRH 208 was replaced with the spare, HRH 220. During the next two days, HRH 220 was consistently above HRH 219, by about 0.5°C during the day and 1.0°C at night. Thus, replacing the module resulted in a swing of about 3.5°C at night compared to HRH 219, from 2.0°C low to 1.5°C high (Fig. 2-3).

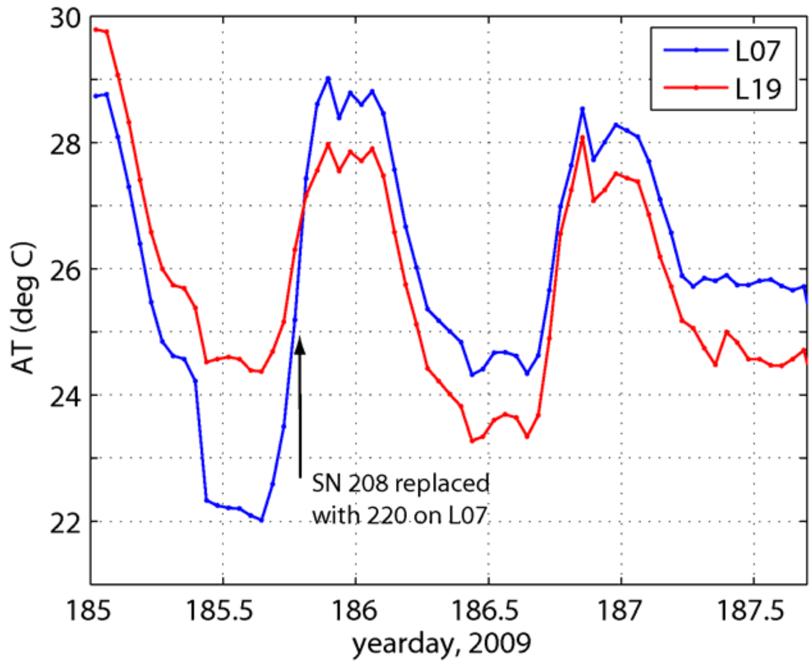

Figure 2-2: Comparison of air temperature (AT) data during 4-6 July. HRH 208 replaced HRH 220 on Logger 07 at 1930 h UTC on 4 July. HRH 219 was on Logger 19.

Night-time AT disagreement had been seen before on the pier at the UH Marine Center, and examination of the WHOTS-4 cruise report (Whelan et al., 2008) showed that night-time AT differences approaching 1.0°C were characteristic of two modules that were later shown to be working properly (these modules agreed to within 0.1°C during the day). The WHOTS-4 night-time discrepancy was attributed to spatial gradients. To determine whether spatial separation accounted for theWHOTS-6 AT differences, HRH 208 was configured as a stand-alone module and clamped next to RHR 220. After two days, 1 min data were offloaded from the loggers and the stand-alone module for evaluation. The results of this test (Fig. 2-3) showed the adjacent modules (HRH 208 and 220) within about 0.4°C during the day and 0.6°C at night. Two Lascar AT/RH sensors, mounted on the port and starboard extension arms, showed night-time values roughly between SN 220 and 208. Since HRH 219 was consistently lower than HRH 208, HRH 220 and both of the Lascars, the decision was made to replace HRH 219 with HRH 208. This resulted in a significantly reduced night-time AT discrepancy between the L07 and L19 and the buoy was deployed in this configuration.

A series of "sensor function checks," including filling and draining the PRC modules, covering and uncovering the solar modules, and dunking the STC modules in a salt-water bucket, were done during the in-port evaluation period. The results of these checks, and evaluation of hourly Argos data and 1min data offloaded from the loggers for 7-8 July, showed all modules to be functioning as expected (differences between like sensors within accuracy tolerances) with the exception of the HRH AT, as described above.

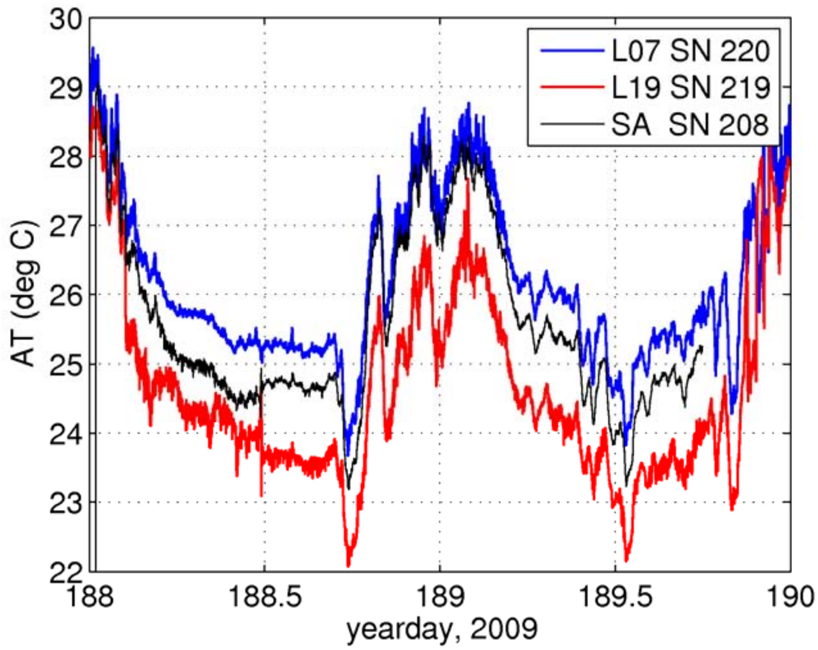

Figure 2-3: Comparison of air temperature (AT) data during 7-8 July. HRH SN 208 was configured as a stand-alone (SA) module and clamped next to HRH 220 on the buoy tower. HRH 219 was at the opposite end of the tower, about 2.4 m away.

d. An AutoIMET (AI) system

An AutoIMET system was installed on the platform above the bridge (Fig. 2-4). It included sensors for barometric pressure, air temperature, relative humidity, precipitation, as well as long- and short wave radiation. Initially, the AutoImet wind sensor was installed on the bridge platform as well. Since both the ship's wind sensor and a sonic wind sensor had been installed there, we moved the AI wind sensor down onto the forward rail of the deck above the bridge, just starboard of the mast structure, in an attempt to estimate air acceleration on the mast platform. Sensor heights were carefully measured by Dr. Frank Bradley.

One-minute sensor averages were recorded internally by the AI logger. In addition, a two-minute data stream was sent serially to a computer in the bridge's chart room. The computer was connected to the ship's internet, thus making the data available in real-time. Automated ftp transfer provided updates to a stand-alone display program of the two-minute data as well as to Nan Galbraith's "argplot" program suite for combined display of hourly AI averages and the buoy data, while Dr. Frank Bradley periodically examined the data via manual ftp transfer.

Experience during the cruise confirmed the importance of real-time monitoring, as it caught the failure of the chart room logging computer when its power cord fell out, after which the computer drained its battery and shut down. Fortunately, the mixing data were noticed on the two-minute display and was able to restart logging and display (note: the one-minute logger-recorded averages were not affected by this break).

The wind sensor entries in the two-minute logger output strings included occasional "drop-outs" (substitutions of "na" for sensor readings). They occurred over periods of roughly an hour, but would not affect every two-minute scan. One such period occurred prior to the ship's departure, and another such period a few days into the cruise. Presumably the one-minute logger data show the same "na" gaps.

Figure 2-4: AUTOIMET Installation aboard *Kilo Moana*

3. WHOTS-6 Mooring Description

a. Mooring Design

The mooring (Fig. 3-1) is an inverse catenary design utilizing wire rope, chain, nylon line and colmega line. The mooring scope (ratio of total mooring length to water depth) is about 1.25. The watch circle has a radius of approximately 2.2 nm (4.2 km). The surface element is a 2.7-meter diameter Surlyn foam buoy with a watertight electronics well and aluminum instrument tower. The two-layer foam buoy is “sandwiched” between aluminum top and bottom plates, and held together with eight 3/4" tie rods. The total buoy displacement is 16,000 pounds, with reserve buoyancy of approximately 12,000 lb when deployed in a typical configuration. The modular buoy design can be disassembled into components that will fit into a standard ISO container for shipment. A subassembly comprising the electronics well and meteorological instrument tower can be removed from the foam hull for ease of outfitting and testing of instrumentation. Two ASIMET data loggers and batteries sufficient to power the loggers and tower sensors for one year fit into the instrument well. Two complete sets of ASIMET sensor modules (Table 3-1) are attached to the upper section of the two-part aluminum tower at a height of about 3 m above the water line. Table 3-2 shows ASIMET sensor specifications. The tower also contains a radar reflector, a marine lantern, and two independent Argos satellite transmission systems that provide continuous monitoring of buoy position. A third Argos positioning system was mounted within an access tube in the foam hull. This is a backup system, and would only be activated if the buoy capsized. For WHOTS-6, a self-contained XEOS Global Positioning System (GPS) receiver and a PCO_2 sampling system were also mounted on the buoy. Sea surface temperature and salinity are measured by sensors bolted to the underside of the buoy hull and cabled to the loggers through an access tube through the buoy foam.

Fifteen temperature-conductivity sensors, two Vector Measuring Current Meters (VMCMs) one MAVS, and two Acoustic Doppler Current Meters (ADCP) were attached along the mooring using a combination of load cages (attached in-line between chain sections) and load bars. All instrumentation was along the upper 155 m of the mooring line. Dual acoustic releases, attached to a central load-bar, were placed approximately 33 m above the 9300 lb anchor. Above the release were eighty 17” glass balls meant to keep the release upright and ensure separation from the anchor after the release is fired. This flotation is sufficient for backup recovery, raising the lower end of the mooring to the surface in the event that surface buoyancy is lost.

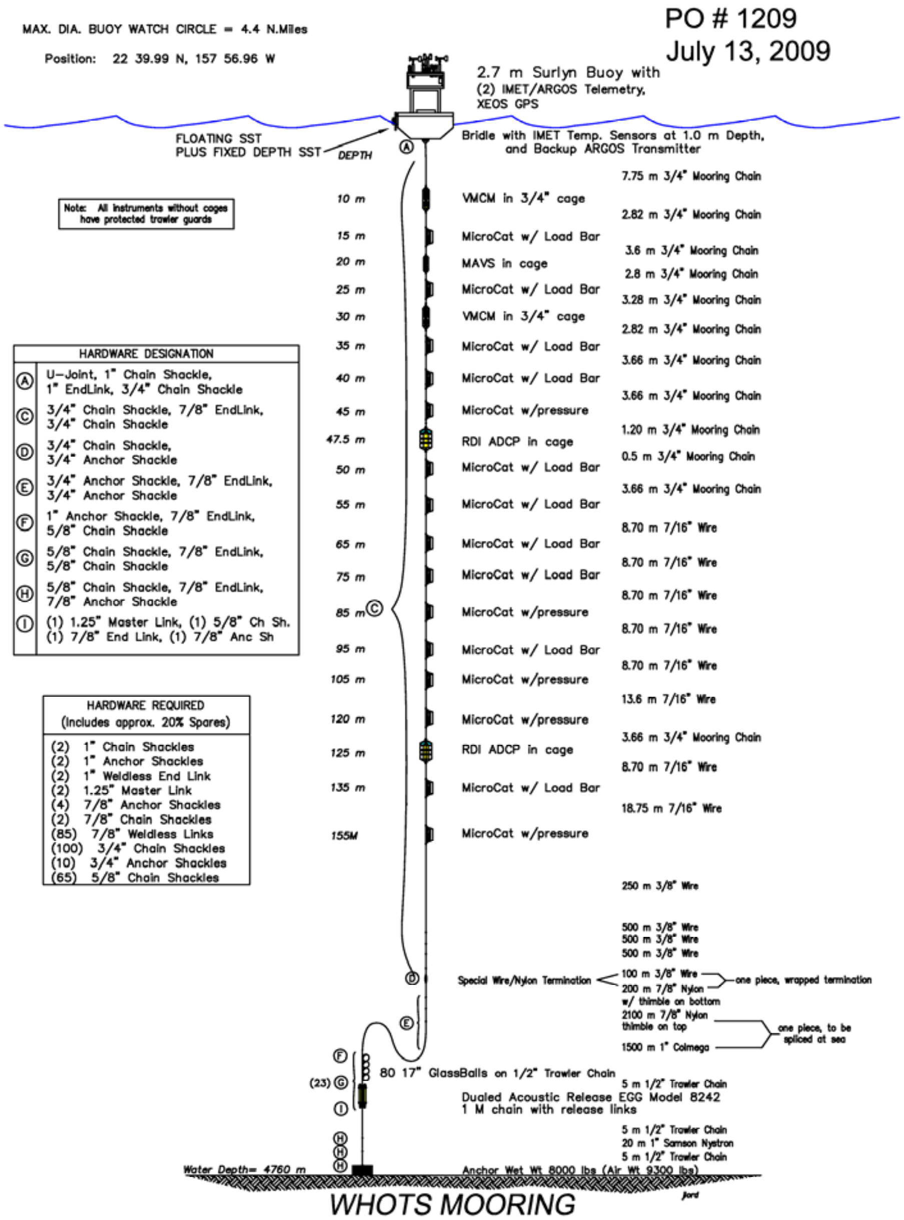

Figure 3-1: WHOTS 6 Mooring Design.

b. Surface Instrumentation

WHOTS 6 Serials/Heights

		System 1	
Module	**Serial**	**Firmware Version**	**Height Cm**
Logger	L-07	LOGR53 V3.21 keil	
HRH	220	VOS HRH53 V3.2	227
BPR	212	VOS BPR53 V3.3 (Heise)	236
WND	218	VOS WND53 V3.5	267
PRC	211	VOS PRC53 V3.4	247
LWR	505	VOS LWR53 V3.5	278
SWR	219	VOS SWR53 V3.3	275
SST	1835		-153
PTT	14637	7563, 7581, 7582	
		System 2	
Module	**Serial**	**Firmware Version**	**Height Cm**
Logger	L-19	LOGR53 V3.10	
HRH	208	VOS HRH53 V3.2	227
BPR	221	VOS BPR53 V3.3 (Heise)	236
WND	211	VOS WND53 V3.5	267
PRC	504	VOS PRC53 V3.4	247
LWR	215	VOS LWR53 V3.5	278
SWR	202	VOS SWR53 V3.3	275
SST	1727		-153
PTT	18136	14663, 14677, 14697	
		Stand-Alone Module(s)	
Module	**Serial**	**Firmware Version**	**Height Cm**
XEOS	611500	L-07 powered	250
PCo2	0019		69
SIS	25702		~
Larcar 1	288	Start 19:00 7/4/2009 60 Minute Samples	198
Lascar 2	249	Start 19:00 7/4/2009 60 Minute Samples	231
TR1060	14882	Start 22:40 7/3/09 300 Second Samples	-127
SBE39	717	Start 22:30 7/3/09 300 Second Samples	Float

Horizontal Distances		
	Cm	
WND	121	WND
LWR	24	LWR
SWR	24	SWR
PRC	144	PRC
BPR	59	BPR
HRH	242	HRH

Table 3-1: WHOTS 6 Serial and Heights

Module	Variable(s)	Sensor	Precision	Short-term Accuracy [1]	Long-term Accuracy [2]
BPR	barometric pressure	AIR Inc.	0.01 mb	0.3 mb	0.2 mb
HRH	relative humidity	Rotronic	0.01 %RH	3 %RH	1 %RH
	air temperature	Rotronic	0.02 °C	0.2 °C	0.1 °C
LWR	longwave radiation	Eppley PIR	0.1 W/m^2	8 W/m^2	4 W/m^2
PRC	precipitation	RM Young	0.1 mm	[3]	[3]
STC	sea temperature	SeaBird	0.1 m°C	0.1 °C	0.04 °C
	sea conductivity	SeaBird	0.01 mS/m	10 mS/m	5 mS/m
SWR	shortwave radiation	Eppley PSP	0.1 W/m^2	20 W/m^2	5 W/m^2
WND	wind speed	RM Young	0.002 m/s	2%	1%
	wind direction	RM Young	0.1 ^{o}	6 ^{o}	5 ^{o}

[1] Expected accuracy for 1 min values.
[2] Expected accuracy for annual mean values after post calibration.
[3] Field accuracy is not well established due to the effects of wind speed on catchment efficiency. Serra et al. (2001) estimate sensor noise at about 1 mm/hr for 1 min data.

Accuracy estimates are from Colbo and Weller (2009) except conductivity, which is from Plueddemann (unpublished results).

Table 3-2: WHOTS-5 ASIMET sensor specifications

XEOS GPS

A Xeos Melo-DL GPS beacon and data logger was installed on WHOTS-6 (imei number 300034012611500). The Melo-DL is based on the standard Xeos Technologies Melo beacons, but modified to allow a programmable combination of GPS position transmission via Iridium satellite and internal logging of GPS data. The configuration is controlled by four variables: TS, GPS, BURST and SAMPLE. For WHOTS-6 iridium transmissions were obtained every 30 min (GPS = 30), and each logged record was a 6 min burst at 20 second intervals (BURST = 5 min, SAMPLE = 20 sec). The Melo-DL is programmed using an email message sent via iridium. The unit can also be interrogated via iridium to determine its status. An interrogation on 10 July 2009 at 11 AM confirmed operational status, including maximum received signal strength (RSSI 5), 8 satellites being tracked, and battery voltage of 15.01 V.

PCO_2

The WHOI Hawaii Ocean Time-series Station (WHOTS) is located near the HOT shipboard time series site (22.75°N, 158°W) in order to maximize the utility of both data sets. There are several advantages of this site. These include: (1) A rich historical database is available for the site; this is useful for setting up new moored instruments, as well as facilitating intercomparisons and interpretations; (2) The HOT site is well away from sources of anthropogenic influence, which is especially important for trace metal, dissolved CO_2,

oligotrophic biological and optical, and aerosol studies; (3) The ongoing JGOFS time-series sampling program (approximately monthly frequency) collects a relatively complete suite of physical, chemical (including nutrients and CO_2), and biological data. There are analogous advantages for comparisons and calibrations of present and emerging sensors; (4) Remote sensing data (SeaWiFS, AVHRR, TOPEX/Poseidon and ERS-series altimetry, QuikScat, MODIS, and weather images) are collected, thus providing complementary measurements for our study and *vice versa*; (5) there is a documented need for high temporal resolution/mooring data at the site because of undersampling and aliasing as described above; (6) there is a reasonably high probability of passage of intense storms and occasional hurricanes; (7) other testing is either ongoing or planned from other platforms near the HOT site (e.g., AUVs); and (8) the region is often used for other scientific studies that can be used to enhance the HOT and WHOTS data sets and *vice versa*.

Adding a pCO_2 system to the WHOTS mooring expands the OceanSITES moored pCO_2 network. The current network is developing in the North Pacific. This site provides the next logical step for an expansion.

CO_2 measurements are made every three hours in marine boundary layer air and air equilibrated with surface seawater using an infra-red detector. The detector is calibrated prior to each reading using a zero gas derived by chemically stripping CO_2 from a closed loop of air and a span gas (470 ppm CO_2) produced and calibrated by NOAA's Earth System Research Laboratory (ESRL). For an overview of the system visit: http://www.pmel.noaa.gov/co2/moorings/eq_pco2/pmelsys.htm.

A summary file of the measurements is transmitted once per day and plots of the data are posted in near real-time to the web. To view the daily data visit the NOAA PMEL Moored CO_2 Website: http://www.pmel.noaa.gov/co2/moorings/hot/hot_main.htm. Within a year of system recovery, the final processed data are submitted to the Carbon Dioxide Information Analysis Center (CDIAC) for release to the public.

c. WHOTS 6 Subsurface Instrumentation

WHOI provided 2 Vector Measuring Current Meters (VMCM) as detailed in Table 3-3. Also sea surface temperature sensors were installed on a bracket attached to the buoy hull. These sensors are detailed in Table 3-4.

Instrument	Serial	Depth Meters	Sample	Start Date	Start Time	Spike Start	Spike Stop
VMCM	10	10	1	07-Jul-09	17:00:00	7/10/09 16:02	7/10/09 16:04
VMCM	58	30	1	07-Jul-09	17:00:00	7/10/09 16:02	7/10/09 16:04

Table 3-3: WHOTS-6 VMCM configuration and deployment information

Instrument	Serial	Depth Meters	Sample	Start Date	Start Time	Spike Start	Spike Stop
SBE39	717	FSST	300 Secs	03-Jul-09	22:30:00	7/9/09 22:55	7/10/09 0:19
TR1060	14882	FSST (fixed)	60 Secs	03-Jul-09	22:40:00	7/9/09 22:55	7/10/09 0:19

Table 3-4: Floating SST configuration

UH provided 15 SBE-37 Microcats, an RDI 300 kHz Workhorse acoustic Doppler current profiler (ADCP), and a Nobska MAVS acoustic velocity sensor. The Microcats all measure temperature and conductivity, with 5 also measuring pressure. Table 3-5 provides deployment information for the C-T instrumentation on the WHOTS-6 mooring.

Depth (meters)	Seabird Model/Serial #	Variables	Sample Interval (seconds)	Navg	Time Logging Started	Cold Spike Time	Time in the water
15	37SM31486-6893	C, T	90	1	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 18:35
25	37SM31486-6894	C, T	90	1	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 18:30
35	37SM31486-6895	C, T	90	1	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 18:24
40	37SM31486-6896	C, T	90	1	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 18:19
45	37SM31486-6887	C, T, P	90	1	07/6/09 00:00:00	07/06/09 01:41:00	07/10/09 18:17
50	37SM31486-6897	C, T	90	1	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 19:49
55	37SM31486-6898	C, T	90	1	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 19:53
65	37SM31486-6899	C, T	90	1	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 19:59
75	37SM31486-3618	C, T	150	2	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 20:03
85	37SM31486-6888	C, T, P	90	1	07/6/09 00:00:00	07/06/09 01:41:00	07/10/09 20:06
95	37SM31486-3617	C, T	150	2	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 20:09
105	37SM31486-6889	C, T, P	90	1	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 20:12
120	37SM31486-6890	C, T, P	90	1	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 20:16
135	37SM31486-3634	C, T	150	2	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 20:23
155	37SM31486-6891	C, T, P	90	1	07/6/09 00:00:00	07/06/09 00:51:00	07/10/09 20:27

Table 3-5: WHOTS-6 mooring subsurface instrument deployment information.

The ADCPs were deployed in the upward-looking configuration. The instruments were programmed as described in Table 3-6. The configuration of the MAVS is also included in Table 3-6.

	ADCP S/N 4891	ADCP S/N 1825	MAVS S/N 10260
Frequency (kHz)	300	600	NA
Number of Depth Cells	30	25	1
Pings per Ensemble	40	80	80
Depth Cell Size	4 m	2 m	NA
Time per Ensemble	10 min	10 min	30 min
Time per Ping	4 sec	2 sec	2 sec
Time of First Ping	07/08/09, 00:00	07/10/09, 00:00	07/09/09, 00:00
Time in water	07/10/09, 20:19	07/10/09, 19:48	07/10/09, 18:31
Depth (meters)	125	47.5	20

Table 3-6: WHOTS-6 mooring ADCP and MAVS deployment information.

d. Anti-foul Treatment

E-Paint's products have been refined to best suit the wishes of WHOI- effective products that remain relatively safe to apply. Treatment of the WHOTS-6 mooring was straightforward.

The Surlyn foam buoy hull and bottom plate were treated with E-Paint Sunwave +. Two gallons were applied to the foam hull and bottom plate.

E-Paint Biogrease was used to coat the two SBE 37s mounted to the bottom of the buoy. Sunwave and gray transducer paint was used the floating SST and fixed SST.

E-Paint ZO was also used to treat the instruments mounted on the mooring line down to 50 meters. The shield over the conductivity cell on SBE 37s was coated on both sides. The conductivity cell was coated as well. The VMCMs, propellers were treated with E-Paint. VMCM stings were painted with gray transducer paint prior to deployment.

4. WHOTS-6 Mooring Deployment

a. Deployment Approach

The nominal WHOTS deployment site is 22°46'N, 157°54'W, near the eastern edge of the Station Aloha circle. In order to accommodate the option of deploying the replacement mooring prior to recovering the one previously deployed, a second site was chosen at 22°40'N, 157°57'W, at the S-SE edge of the Station Aloha circle and about 6 nm away from the first site. The "eastern site" was occupied by WHOTS-1, 2, 3 and 5. The "southeast site" was occupied by WHOTS-4 and was the target site for WHOTS-6. Bathymetry data from the archives of the Hawaii Mapping Research Group (HMRG) as well as multi-beam surveys during previous WHOTS cruises (e.g., Whelan et al., 2007; 2008) indicated depths of 4700 ± 20 m, near the eastern site and 4760 m ±20 m near the southeast site. The nominal WHOTS mooring design is for a depth of 4700 m ±100 m, so no adjustments in mooring length are necessary for either site.

Winds from the shipboard anemometers and currents from the shipboard ADCP were noted while maneuvering to WHOTS-6 deployment starting point. Winds were relatively steady at 15 kt from the E, and currents were 0.2 kt to the N (Fig. 4-1). It appeared that the best approach would be from W-NW of the anchor drop site. A 30 min set-and-drift test was conducted by the bridge, indicating steady movement along 280º. It was decided to steam to a starting point approximately 6.0 nm from the drop point at a course of 280º and hold position to set up for deployment operations. The waypoint for the bridge was the anchor drop point, 0.2 nm beyond the desired anchor position to allow for an expected fall-back of about 350 m. Deployment operations began at about 0800 h (local) on 10 July with the *Kilo Moana* at a distance of 6.0 nm from the drop site and took about 7.5 h to complete. The ship's track spanning the deployment period, the post-deployment anchor survey, and the approach to the buoy after the anchor had settled out is shown in Fig. 4-2.

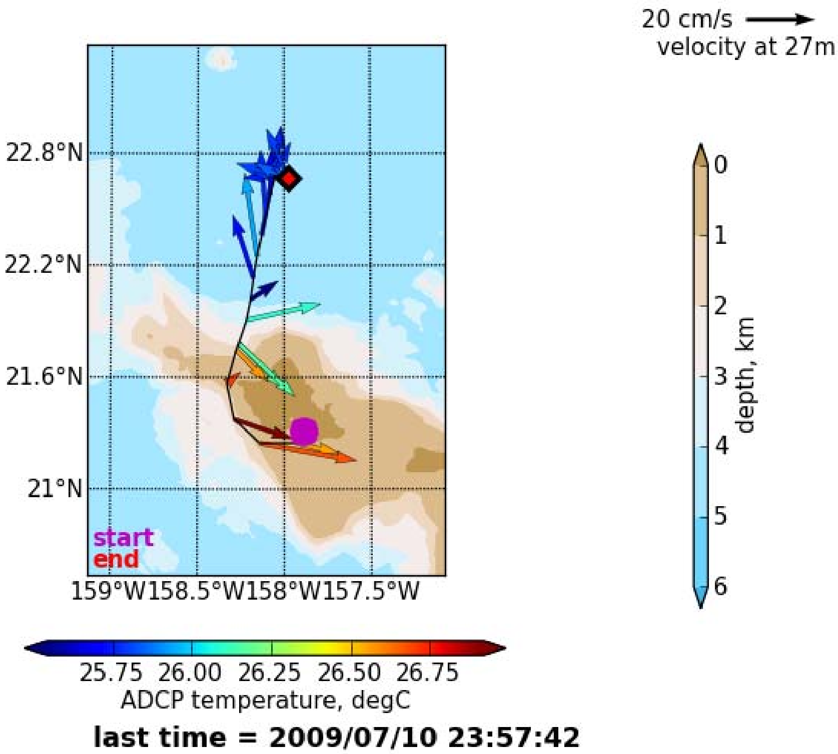

Figure 4-1. Surface currents from the *Kilo Moana* shipboard ADCP prior to the WHOTS-6 mooring deployment.

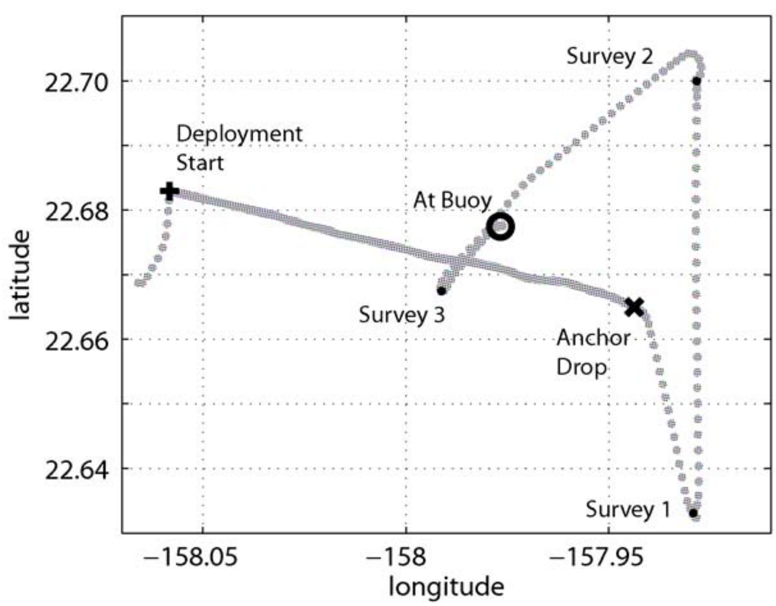

Figure 4-2. Ship track during WHOTS-6 deployment. The period shown includes the deployment start (+), the deployment approach, the anchor drop (x) and the anchor survey. At the end of the survey the ship moved to a point about 0.2 nm from the buoy (o).

b. Deployment Operations

Mooring operations on the *Kilo Moana* (KM) would require that all work be done through the stern A-frame. The length of the deck on the port and starboard sides is 18 feet, and the central portion of the main deck is only about 34 feet square. All operations must take place in the central portion of the main deck. The buoy, mooring winch, and two capstans must also fit in this area.

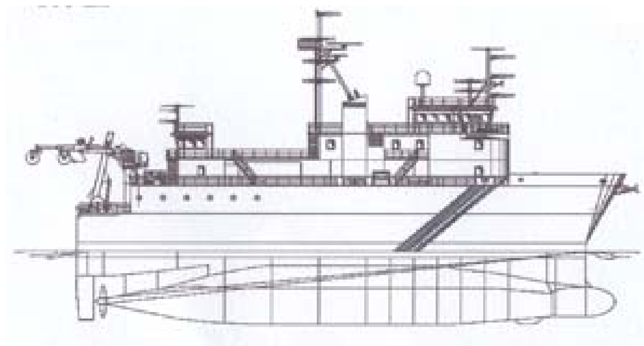

Figure 4-3: *Kilo Moana*

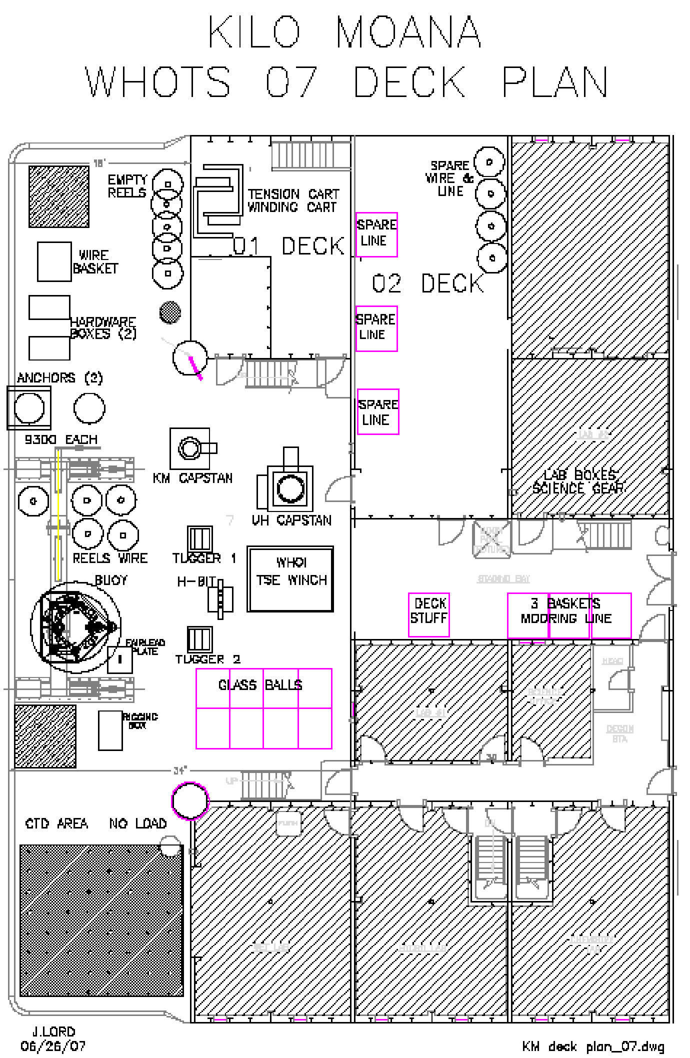

Figure 4-4: *Kilo Moana* Deck Plan

Setup for the mooring deployment included running a 3/4" inch spectra working line through the turning blocks on the A-frame, and over the flag block in the center of the A-frame. A Gifford block was shackled to the working line under the A-frame, and the ship's small gray capstan was used to haul the block up and suspend it just below the flag block. The A-frame was positioned so the block hung slightly aft of the transom. The working end of the spectra was stopped off on a cleat.

Instruments from the surface to 45 meters were pre-rigged with chain and hardware at the top of the load bar or instrument cage. Instruments below 45 meters were pre rigged with wire rope or chain shots shackled to the bottom of the load bar or cage. Doing this work in advance saved time during the actual deployment process.

To begin the mooring deployment a shot of wire rope was passed from the mooring winch through the Gifford block and lowered to the deck. The 85-meter spectra working line was shackled to the bottom of the 1.22 meter ¾" mooring chain at the 45-meter MicroCat instrument. The working wire from the winch was shackled into a link at the top of the 3.66 meter shot of ¾" chain. To begin the deployment the winch hauled in wire to suspend the chain and MicroCat from the A-Frame. Next, the A-Frame was positioned so the instruments cleared the transom. The winch payed out wire to lower the instruments and chain to the water. A person tending the 85-meter working spectra line on a cleat payed out line approximately equal to what was being lowered into the water.

When the top of the chain above the MicroCat was about .5 meters above the transom, a ½" screw pin shackle and 5/8" pear link was shackled to the chain. A stopper line was attached to the pear link and then was made fast to the deck cleat. The winch lowered the chain to the deck and the next segment of the mooring was shackled to the 7/8" end link. The procedure for inserting the 40 meter MicroCat and the rest of the instruments above 45-meters included: shackling the bottom of the instrument cage or load bar into the link at the top of the instrument array suspended in the water, lifting the instrument and attached chain shot off the deck with the winch, paying out with the winch and Spectra working line, stopping off the chain, and repeating this process.

The 7.75 meter shot of chain above the 10 meter depth VMCM was stopped off using a pear link shackled into the chain about 2 meters from the top. A slip line was passed through the link and secured to a cleat. The port side crane was used to move the buoy from its position under the A-frame on the starboard side to a position generally centered under the A-frame. A ¾" shackle was used to attach the top section of mooring chain to the universal.

To prepare for the buoy deployment cleats were set up on each side of the buoy hull. Slip lines were passed through the handling bails on the buoy hull and also under the wind vane and secured to the deck cleats. A "west coast" quick release was rigged to the buoy's lifting bale and attached to the working line on the A-frame. The ship was instructed to move ahead slowly. When all preparations for the deployment were complete, lines and straps securing the buoy were removed. The slip line holding the mooring tension was slowly removed and the mooring load was transferred to the buoy.

The buoy was lifted off the deck with the large capstan and working line rigged to through the A-frame. The A-frame was moved back, and slip lines kept the buoy in check as it moved out beyond the transom of the ship. When the A-frame was fully extended, the port slip line and slip line from the wind vane was removed. This allowed the buoy to spin 180 degrees and provide a better angle for the quick release line. The buoy was slowly lowered into the water, and once it settled in the quick release was tripped. The starboard slip line was slowly pulled free of the buoy as the ship moved away from it.

As the ship moved away from the buoy, more of the Spectra working line attached to the bottom of the mooring chain were payed out to keep the tension down. As the buoy settled in behind the ship and everything appeared stable, this working line was slackened and removed from the cleat. The ship speed was reduced to just enough to provide steerage, and the large capstan was used to pull in the working line coming from the deployed mooring chain.

When the end of the working line and the bottom of the chain below the 45-meter MicroCat was pulled over the transom, a stopper lines was attached to the link at the bottom of the chain. The working line was removed. The 47.5-meter ADCP was moved into position and shackled into the link. The bottom of the ¾" chain section was shackled into the wire on the winch. The winch hauled in on the wire until it had the load from the mooring. The stopper line was slacked off and removed.

The winch payed out wire until the bottom end of the ¾" chain was about 1 meter above the deck, the winch stopped and the stopper line was attached to the link in the chain. The winch wire was lowered to the deck and removed, and the next instrument and wire shot was inserted into the line. The procedure continued until all instruments had been deployed.

The remaining wire and nylon on the TSE winch was payed out through the hanging Gifford block on the A-frame. Before the wire to nylon transition, the block was lowered to hang about 3 feet over the deck. A heavy duty H-bit was moved into position about 20 feet from the transom and on the center line. The end of the nylon was stopped off and the winch leader removed.

The top of the 2000 meters of 7/8" nylon was shackled to the nylon that was stopped off. The slack part of the nylon was dressed over the H-bit. The stopper line was slacked off and the load transferred to the nylon on the H-bit. With a few science personnel tending the line in the baskets, one person tends the H-bit, and another person spraying cooling water onto the H-bit, deployment of the synthetic lines resumed.

With roughly 40 meters of the colmega line remaining, payout was stopped and a Yale grip and stopper line was used to take tension off the H-bit. The winch leader was shackled into the end of the colmega line and wound on the winch. With some slack remaining, the colmega was removed from the H-Bit. The winch then took up the remaining slack. The Yale grip and stopper line was removed. The TSE winch payed out the mooring line until the thimble was approximately 2 meters from the ship's transom. At this point, the hanging block was lowered to the deck and removed.

The next step was the deployment of 80 glass balls. The glass balls were bolted on 1/2" mooring chain in four ball (4 meter) increments. The port crane was used to lift each string of glass balls out of the wire baskets and lower them to the deck. The first string of balls was dragged aft and connected to the end of the colmega line. The winch leader was then connected to the string of balls. The winch leader was pulled tight, and the stopper line was eased out and disconnected. The winch payed out until 3 balls were beyond the transom. The stopper line was then attached to the link at the end of the string of balls. Another set of glass balls were then dragged into place and shackled into the mooring. This procedure continued until all 80 glass balls were deployed. A five meter shot of ½" chain was shackled into the last section of glass balls and stopped off with approximately 2 meters of chain remaining on the deck.

At this point, the ship was still approximately 1.5 nm from the target drop position. The ship towed the mooring toward the drop position in this configuration. Approximately 0.5 nm from the site, the final sections of the mooring were prepared. The tandem-mounted acoustic releases were shackled into the mooring chain at the transom. Another 5-meter shot of chain was attached to the bottom link on the dual release chain. A 70 foot ¾" nystron slip line placed through the 7/8" link which was shackled to the 20 meter shot 1 inch Samson Nystron. The two ends of the slip line were bowline to the winch leader. The slip line and the 20 meter shot of nystron was wound on the winch. The 5 meter ½" chain from the releases was shackled to the 20 meter shot of nystron.

A ½" chain hook was shackled into the working line hanging from the A-frame and hooked into the chain just below the acoustic releases. The working line was pulled up with the capstan, lifting the releases off the deck. The winch payed out and the A-frame was moved out until the releases were clear of the transom. The working line was lowered and the chain hook removed from the mooring. The winch continued to pay out until the end of the 20-meter nylon was near the transom.

The anchor, positioned on the port side, just outboard of the A-frame was rigged with a 5-meter shot of ½" chain. The 5 meter shot was brought around the aft side of the A-Frame and shackled to the 20 meter shot. The bolts holding the anchor tip plate to the deck were removed. The chain lashings on the anchor were removed, and an expendable back stay was rigged on the anchor to secure it. With 100 meters to the drop site, the winch payed out slowly until anchor had the load. The ¾" slip line was removed from the winch and was slowly slipped out through the 7/8" link.

The crane was positioned over the forward end of the tip plate and hooked into the tip plate bridle. As the ship approached the launch site, the backstay was removed, the crane hook was raised, and the tip plate raised enough to let the anchor slip into the water.

c. Anchor Survey

The anchor survey was done by acoustic ranging on one of the releases to determine the exact anchor position and allow estimation of the anchor fall-back from the drop site. The Edgetech Model 8242XS Dualed Release and Transponder used on the WHOTS mooring is rated to 6000 Meter Depth, 5500 kg load, and 2 years of battery life using alkaline batteries. This unit also includes status reply which indicates a tilted angle or an upright condition and release

status. The anchor survey was conducted sounding on release SN 30847 only. Three positions about 2.25 nm away from the drop site were occupied in a triangular pattern (Fig. 4-2). The WHOI over-the-side transducer and deck box were used to obtain slant range (or travel time) to the release at each station. Triangulation from the three sites using Art Newhall's acoustic survey program gave an anchor position of 22°39.989′N, 157°56.961′W. The fall-back distance was estimated as 336 m. Figure 4-5 shows anchor survey variables used to calculate anchor position.

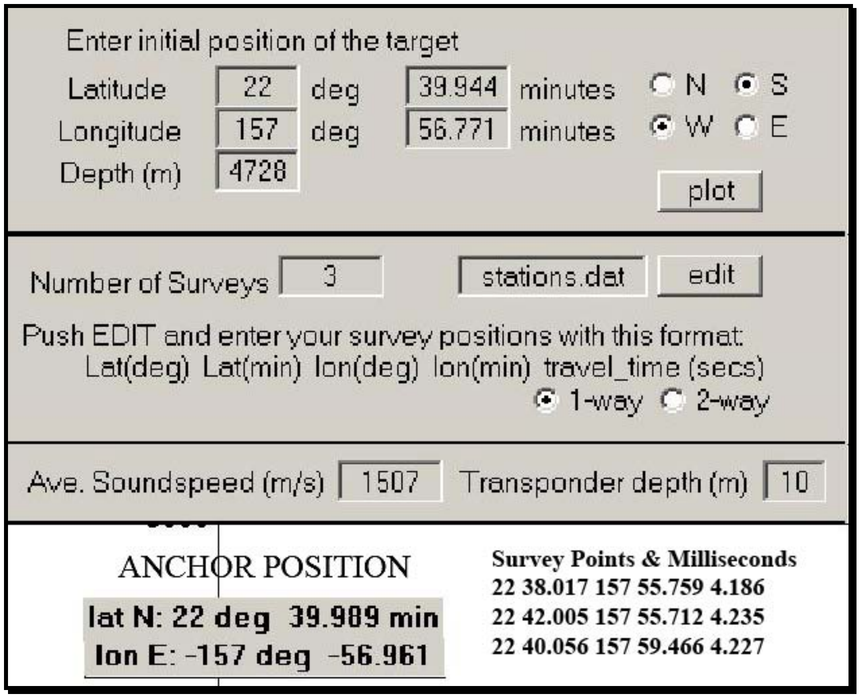

Figure 4-5: WHOTS-6 Anchor Survey. The anchor fall-back was estimated as 336 m or 7.1% of the water depth

5. WHOTS-5 Mooring Recovery

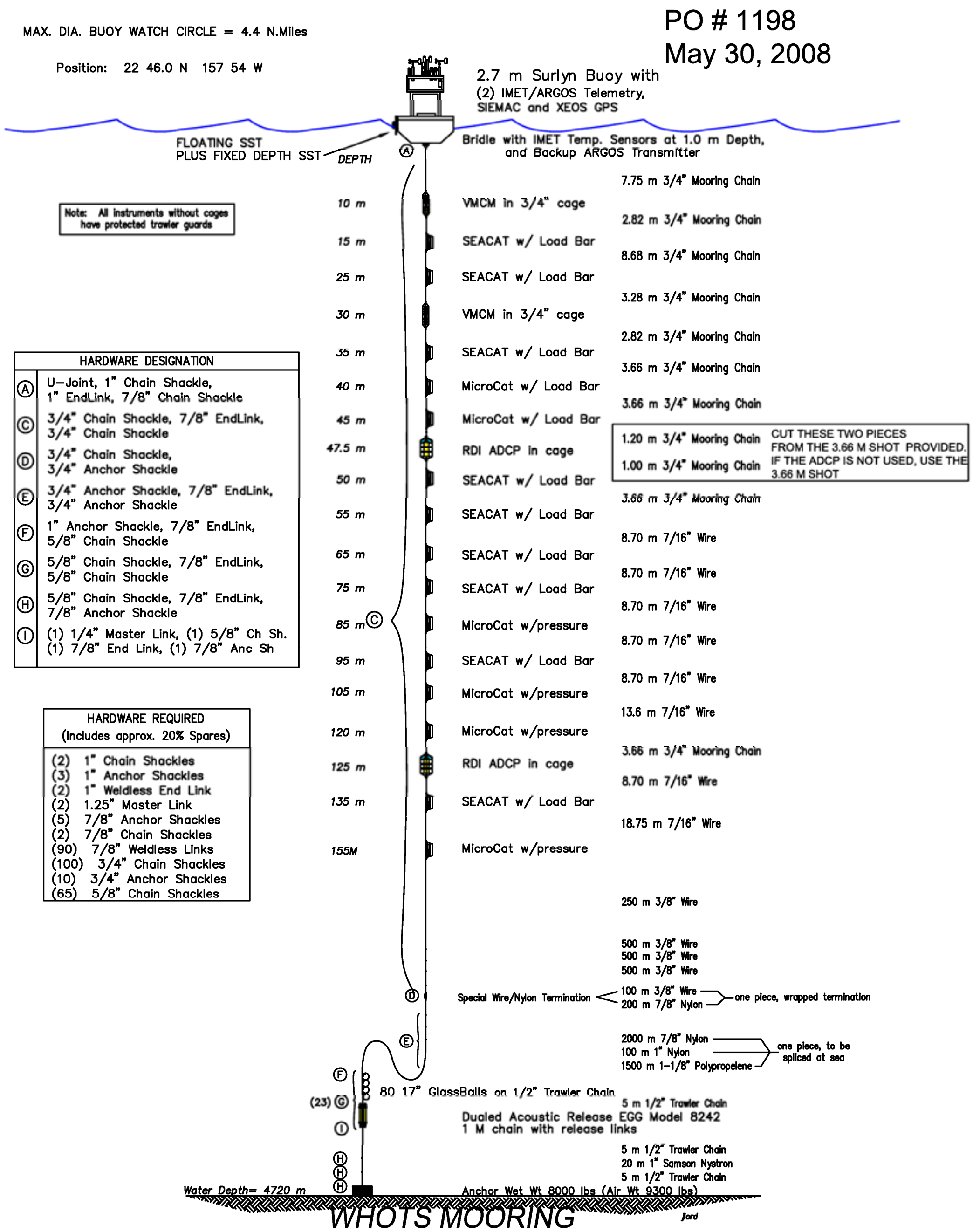

Figure 5-1: WHOTS-5 mooring diagram.

a. Recovery Operations

The WHOTS-5 mooring Figure 5-1 was recovered glass flotation first. The TSE winch, ship's capstan, UH capstan and assorted WHOI deck lines and hooks were used during the recovery. A 5/8" spectra working line was revved through the ship's flag block in the center of the A-frame, and through the turning blocks on the A-frame. The ship's rescue boat was launched and attached an 80 foot pendent to the picking point on the buoy. This pendent was attached in the event the rescue boat could not be due to weather; the hook the line could not be grappled. Two air tuggers were positioned the forward side of the A-frame. The air tuggers were to provide control of the cluster of glass balls as they were lifted out of the water and onto the deck.

The R/V *Kilo Moana* was positioned a ½ nm upwind and off to the side of the anchor position. The acoustic release was ranged and fired, releasing the mooring. The ship held position while continuing acoustic ranging to confirmed that the release was free of the anchor. Once the cluster of glass balls were on the surface, the ship's workboat was launched. The workboat maneuvered to the stern of the ship; the spectra working line with a 3 ton snap hook shackled to it was lowered to the boat. Once the crew on the rescue boat had the working line, they drove to the cluster of balls. The Spectra line was payed out from the ship as the rescue boat made its way to the glass balls. The crew snapped into a section of chain.

As soon as the working line was connected to the chain, the rescue boat was recovered. The slack line was taken up on the capstan. The A-frame was shifted outboard. The capstan hauled in, pulling the glass balls to the stern and lifting them out of the water. The A-frame was shifted inboard close enough to attach air tugger lines to a section hardware. The A-frame shifted inboard until the glass balls were completely over the deck. A stopper line hooked to the link at polypropylene line. The spectra line was removed from the chain and the A-Frame was moved outboard to recover the remaining glass balls, 5 meters of chain, and the tandem releases. The glass balls than had to be disassembled and placed into the wire baskets.

A 50 foot slip line was revved through the Gifford block and bowlined to the thimble on the polypropylene. The Gifford block was hung with the 5/8" spectra roughly 1 meter off the deck. The port side tugger was fair leaded to the Gifford block and hauled the block inboard to the A-Frame. This provided a better lead for the large capstan to haul in on the polypropylene and the nylon. Roughly 2/3 rd's of the polypropylene was recovered with the large capstan. The capstan had mechanical issues so the decision was made to recover the remaining synthetics with the TSE winch. When the TSE drum was filled, a yale grip was placed on the nylon and two stopper lines were attached to a link. The synthetics were off spooled into the wire baskets that are in the staging bay. Once off spooled, the winched leader was shackled to the end of the nylon. The remaining nylon, and 1850 meters of wire rope was wound on the winch.

Recovering the sub-surface instruments went as followed. The instrument was stopped off and made fast to a deck cleat. The winch payed out slowly, and the termination was broken. The instruments were removed and the winch wire was shackled back to the mooring. The winch was hauled in to take the load and the stopper line was removed. The recovery continued that way until the ADCP (48.5 m) was on deck. A slip line was rigged through the link and made fast to a deck cleat. The work boat was launched at this point. With the permission from the bridge,

the mooring was slipped and the ship moved ahead. The deck was rigged out for the recovery of the buoy. The work boat came to the stern and the spectra were passed to them. The work boat was shackled into the soft eye of the 80 meter pendent. After the rescue boat was recovered, the large capstan hauled the buoy in slowly. The capstan hauled the buoy out of the water and the tuggers were attached to the tag line bails. Once on deck, a pear link was shackled into the 3/4" chain and a stopper line was attached to the link and made fast. The buoy was disconnected from the chain and repositioned inboard of the starboard side of the A-frame. The remaining instruments and chain were recovered using the ships crane and stopping off in bights.

b. Surface Instrumentation and Data Return

The WHOTS-5 mooring was outfitted with dual ASIMET systems on the buoy, as well as a pCO2 system prepared by PMEL and several stand-alone sensors. The mooring design and buoy instrumentation were very similar to that of WHOTS-6 (Sec. 3), the two minor differences being: (1) WHOTS-5 deployed both Xeos and Seimac GPS whereas WHOTS-6 used only Xeos, (2) WHOTS-5 deployed one Lascar AT/RH recorder and one ASIMET HRH, whereas WHOTS-6 used two Lascars. Details of the WHOTS-5 configuration are provided in Whelan et al. (2009) and summarized in Table 5-1 and Table 5-2 below.

ASIMET

Data return from the two ASIMET systems was very good, with only one significant failure – the System-2 (L-10) WND module failed on 8 March 2009. The remaining sensors recorded 1 min data for the full 368 days, and showed good performance (Figs. 5-2 to 5-4). Minor data quality issues included a persistent difference of 2-3% between the two RH sensors and a gradually increasing difference between the two conductivity sensors.

The consequence of the System-2 WND failure is seen in Fig. 5-4, where the east and north winds for L-10 shift to zero between yearday 400 and 450. Upon recovery, the L-10 WND module was missing its propeller and had a bent propeller shaft (Fig. 5-5). Thus, mechanical damage was the likely cause of the failure. However, inspection of Fig. 5-4 also shows that the L-10 east wind begins to disagree with L-09 near yearday 350 and the L-10 north wind is offset from L-09 throughout the record. Subsequent to deployment of the WHOTS-5 mooring, it was determined that the WND modules suffered from the anti-bird wire being too close to the housing. Specifically, the wire assembly was found to be magnetic (despite the wire itself being stainless steel) and, when placed close to the WND module housing (Fig. 5-5), affected the compass and thus the wind direction. This accounts for differences in wind components seen in Fig. 5-4. An initial, relatively constant offset of about 36 deg between L-09 and L-10 wind direction became more variable after yearday 250. Upon recovery, but prior to removing the WND modules from the tower, the compass readings of both modules were recorded before and after removing the anti-bird wire from the tower. The compass on the L-09 system (SN 219) changed by about 50^o and that on the L-10 system (SN 205) by about 25^o.

System 1

Module	Serial	Firmware Version	Height Cm
Logger	L-09	LOGR53 V3.21	------
HRH	227	VOS HRH53 V3.2	223.5
BPR	505	VOS BPR53 V3.3 (Heise)	233.0
WND	219	VOS WND53 V3.5	260.5
PRC	214	VOS PRC53 V3.4	246.0
LWR	205	VOS LWR53 V3.5	285.0
SWR	208	VOS SWR53 V3.3	285.0
SST	1419	SM 485 V 2.3b	-156
PTT	------	IDs: 27356, 27364, 27413	------

System 2

Module	Serial	Firmware Version	Height Cm
Logger	L-10	LOGR53 V3.21	------
HRH	216	VOS HRH53 V3.2	223.5
BPR	506	VOS BPR53 V3.3 (Heise)	233.0
WND	205	VOS WND53 V3.5	260.5
PRC	210	VOS PRC53 V3.4	246.0
LWR	210	VOS LWR53 V3.5	285.0
SWR	207	VOS SWR53 V3.3	285.0
SST	1306	SM 485 V 2.3b	-156
PTT	------	IDs: 7561, 27415, 27416	------

Stand-Alone Module(s)

Module	Serial	Firmware Version	HeightCm
Seimac GPS	67699	------	245.0
Xeos GPS	9060	------	248.0
IMET HRH	231	VOS HRH53 V3.2	211.0
Lascar AT/RH	11823	------	214.0
SIS	268	PTT ID= 25702	------

Table 5-1: WHOTS-5 ASIMET System Configuration

WHOTS-5 ASIMET module heights and separations

Module	Relative [1] Height (cm)	Absolute [2] Height (cm)	Horizontal Sep. (cm)	Measurement Location
SWR	285	350	24	top of case
LWR	285	350	24	top of case
WND	260.5	325.5	123	middle of vane
PRC	246	311	150	top of cylinder
BPR	233	298	59	center of plate
HRH	223.5	288.5	256	center of shield
STC	-156	-91	10	center of shield

[1] Relative to buoy deck, positive upwards
[2] Relative to buoy water line at 65 cm below deck, positive upwards

Table 5-2: WHOTS-5 ASIMET Heights and Separations

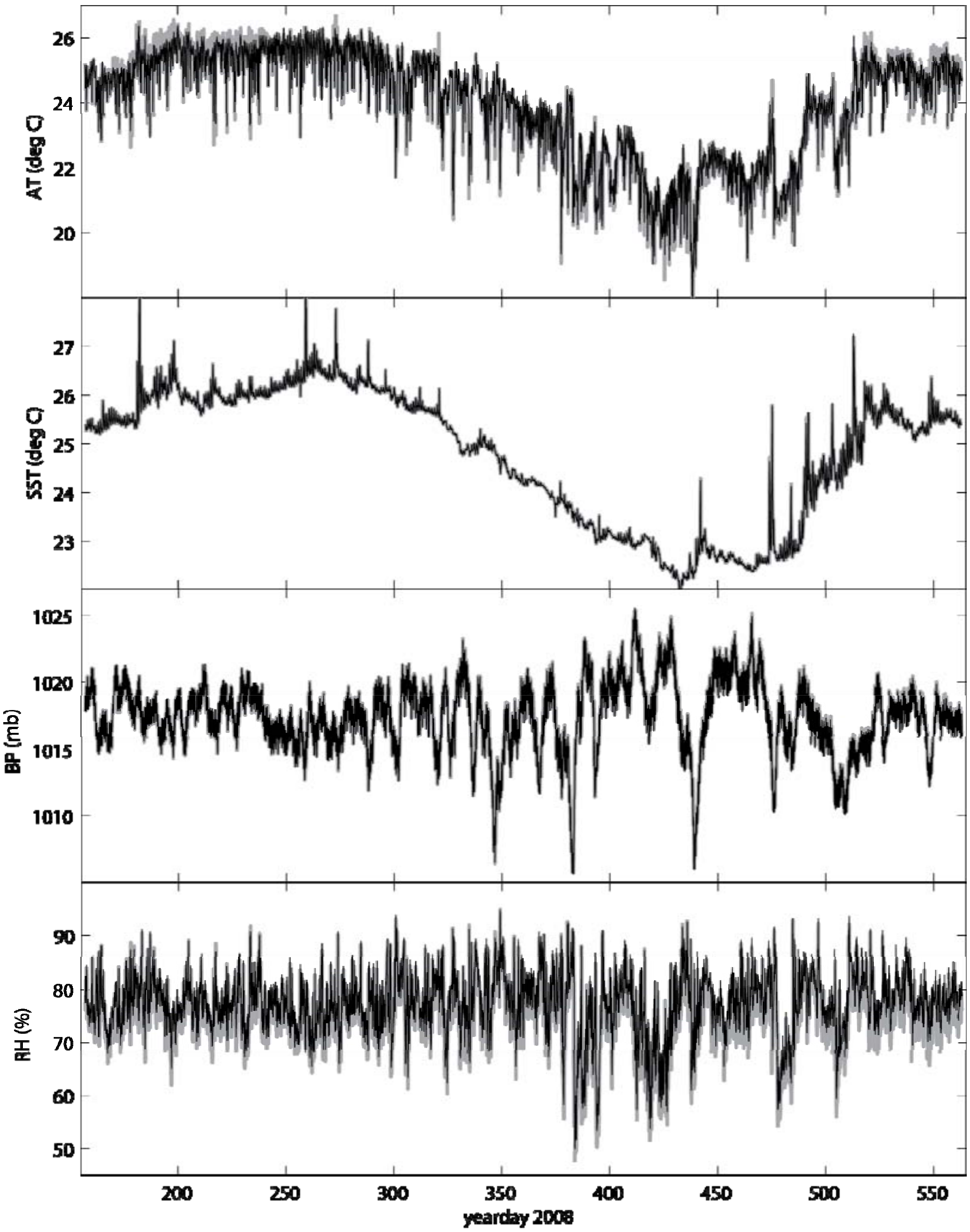

Figure 5-2. WHOTS-5 meteorological variables: Part 1. Raw data from ASIMET System 1 (gray) and System 2 (black) averaged to 1 hour. Variables shown from top to bottom are: Air temperature (AT, ^{o}C), sea surface temperature (SST, ^{o}C), barometric pressure (BP, mb) and relative humidity (RH, %).

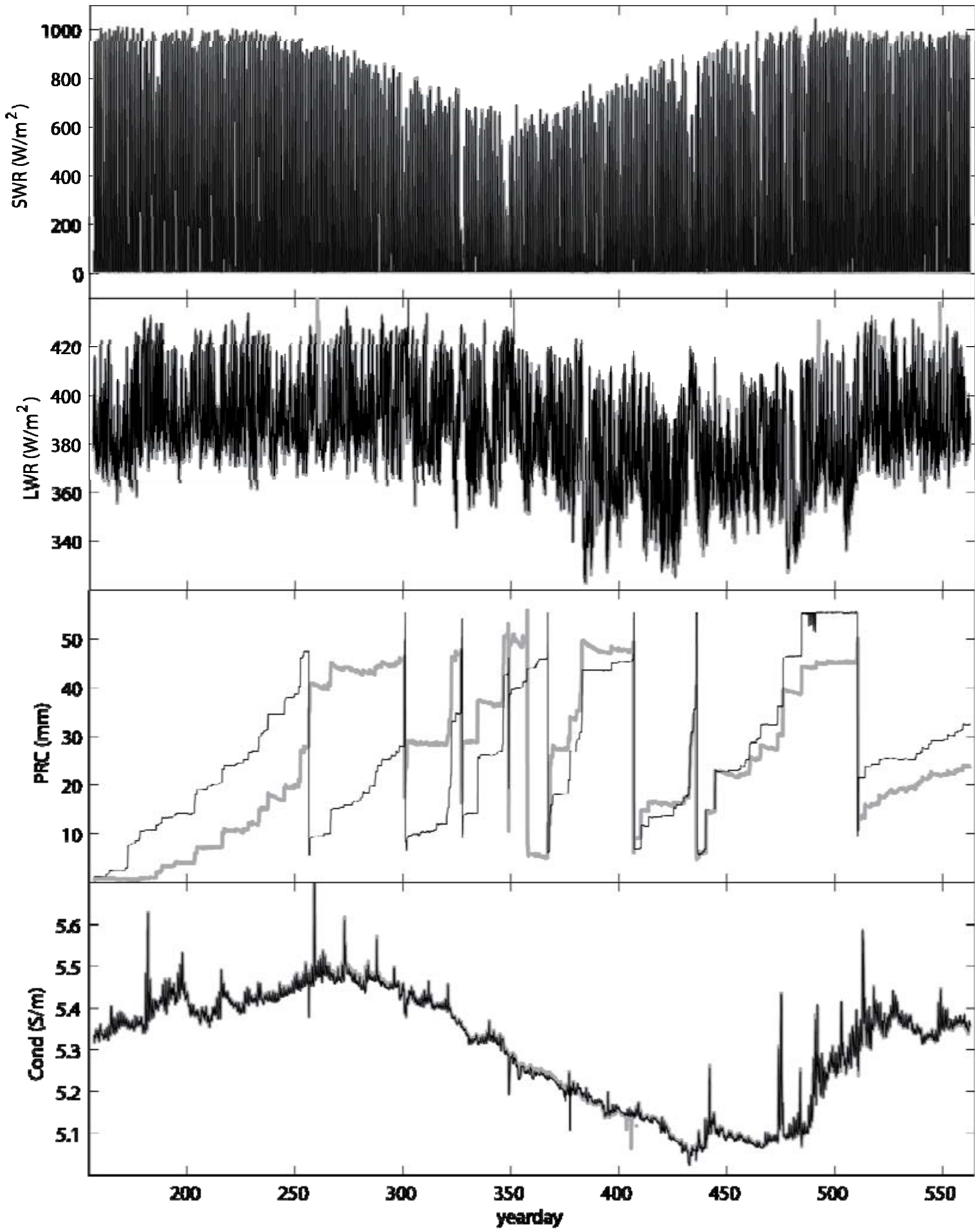

Figure 5-3. WHOTS-5 meteorological variables: Part 2. Raw data from ASIMET System 1 (gray) and System 2 (black) averaged to 1 hour. Variables shown from top to bottom are: shortwave radiation (SWR, W/m^2), longwave radiation (LWR, W/m^2), precipitation level (PRC, mm) and sea surface conductivity (Cond, S/m).

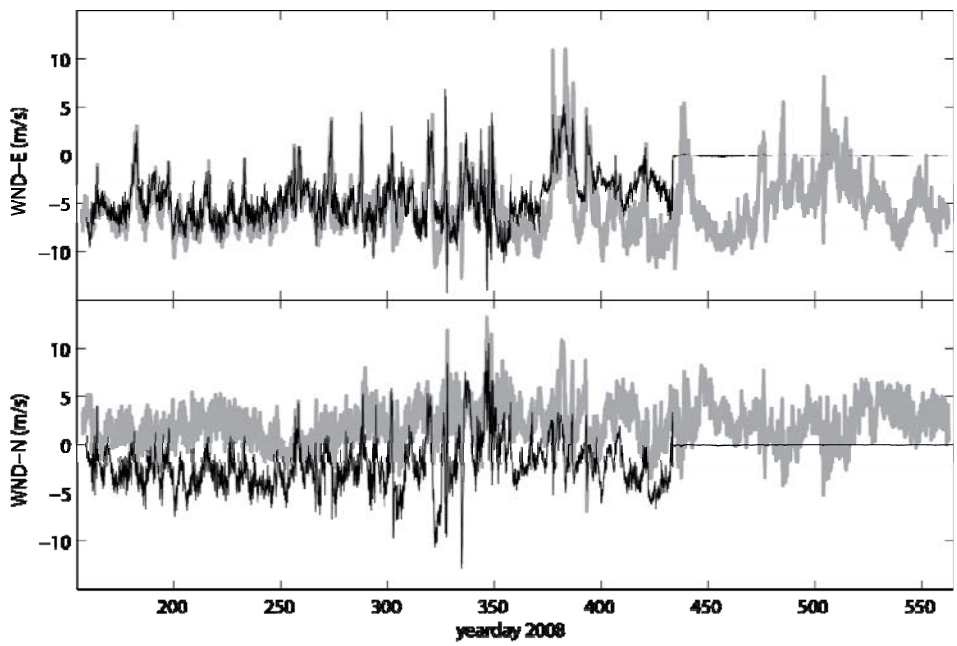

Figure 5-4. WHOTS-5 meteorological variables: Part 3. Raw data from ASIMET System 1 (black) and System 2 (gray) averaged to 1 hr. Variables shown from top to bottom are: east wind component (WND-E, m/s), north wind component (WND-N, m/s). Directions are in "oceanographic" convention– direction towards.

Figure 5-5. WHOTS-5 WND module SN 205 after buoy recovery. Missing propeller and bent shaft are evident. Note also the near proximity of anti-bird wire to the module housing.

Lascar AT/RH

WHOTS-5 included one Lascar EL-USB-2 air temperature/relative humidity (AT/RH) stand-alone module as a backup to the ASIMET systems. The Lascar has a stated accuracy of 2°C and 3.5%, respectively, for AT and RH. In order to run for the duration of the deployment, the Lascar used a one hour sample interval. The WHOTS-5 Lascar returned a complete record and compared well with an ASIMET HRH module, considering the lower precision and longer sampling interval (Fig. 5-6).

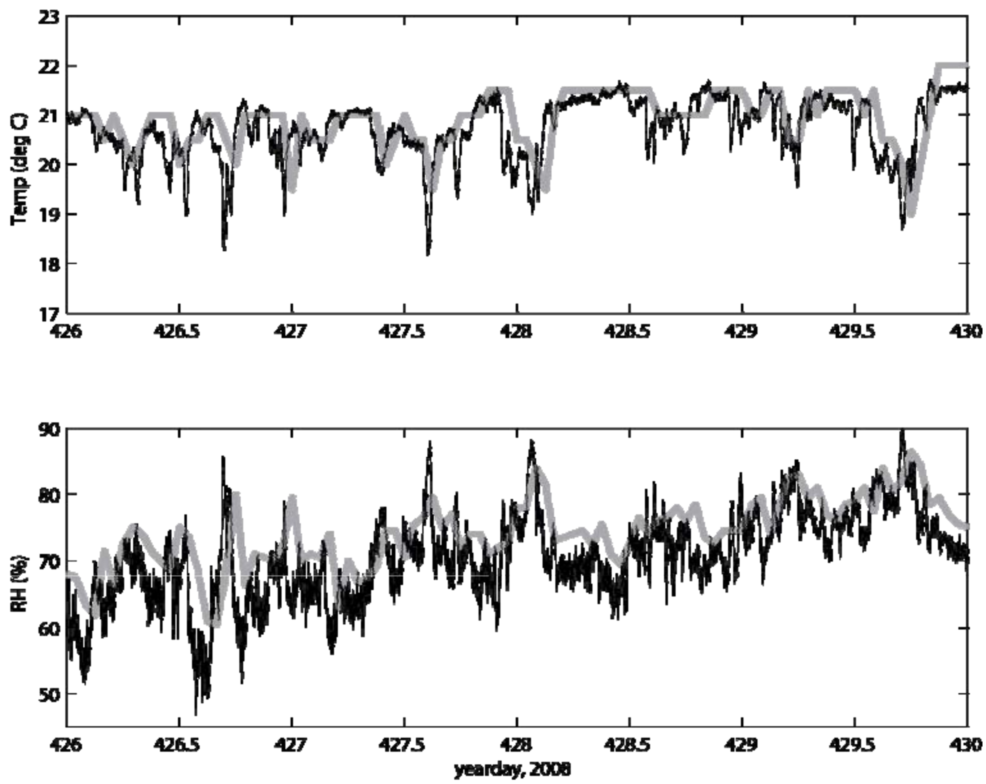

Figure 5-6: Time series of AT (upper), and humidity (lower) for the Lascar (grey) and ASIMET HRH SN 227 (black) for a 5 day period during the WHOTS-5 deployment. The reduced precision and temporal resolution of the Lascar relative to the ASIMET are evident. Timing offsets, which can be corrected in post-processing, are also evident.

Floating SST

Internally logging Sea-Bird SBE-39 (SN 1447) and RBR TR-1050 (SN 10986) temperature sensors were mounted beneath a foam flotation cylinder on the outside face of the buoy hull. Vertical rails allowed the foam to move up and down with the waves, so that the sensor measured the SST within the upper 10-20 cm of the water column. A portion of the data records from the two floating SSTs are shown in Fig. 5-6 along with SST from the SBE-37 connected to the ASIMET system on the buoy. The SBE-39 recorded 106,000 records at sample interval of 5 min, but suffered a time jump at yearday 204. After the jump, times are nonsensical, although temperature values appear reasonable (see Fig. 5-7). The RBR TR-1050 failed on 5 Nov 2008 after 154 days of operation.

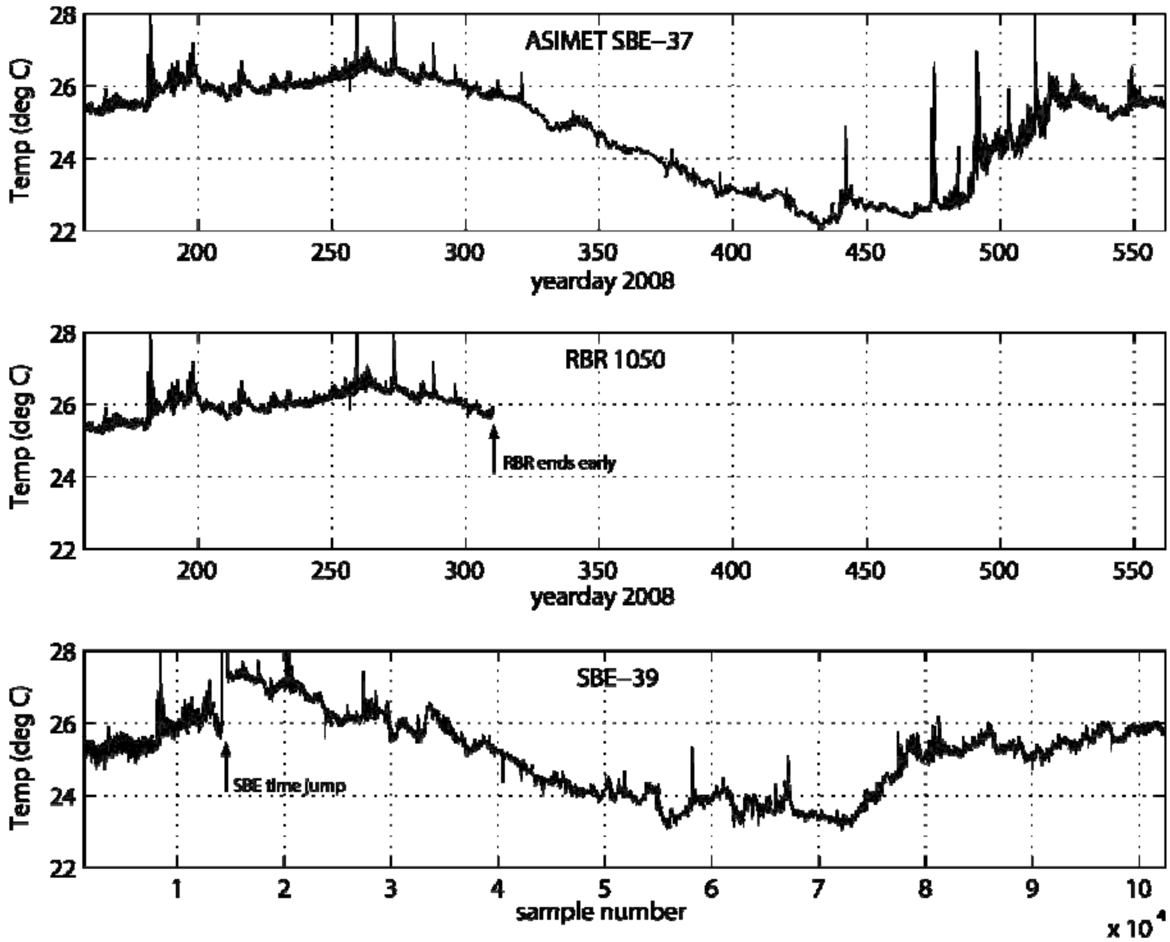

Figure 5-7: Time series of SST from SBE-37 on the WHOTS-5 buoy (upper), RBR TR-1050 floating SST (middle) and SBE-39 floating SST (lower).

GPS

An internally logging Seimac III GPS unit and a Xeos Melo-DL GPS logger were deployed to monitor buoy position. Performance of the Seimac had been poor on previous deployments. For WHOTS-4 and WHOTS-5 the ASIMET logger code was modified to power-cycle the Seimac once per day in an attempt to improve performance. Unfortunately, it appears that the Seimac failed on 19 June 2008, just 14 days after the WHOTS-5 mooring deployment. A more detailed evaluation of the Seimac GPS data awaits translation of the NMEA records. A firmware bug prevented offloading of the Xeos Melo-DL data at sea, but 540,606 records were later recovered. Preliminary evaluation shows that internally recorded data (bursts at 30 min intervals) end on 15 June 2009, while positions transmitted via Iridium (4 h intervals) continue until mooring recovery on 15 July 2009.

c. WHOTS-5 Subsurface Recovery

For the fifth WHOTS mooring deployment that took place on 4 June 2008, UH provided 6 SBE-37 Microcats, 9 SBE-16 Seacats, an RDI 300 kHz Workhorse ADCP, and a 1.2 MHz RDI Workhorse ADCP. WHOI provided 2 VMCMs, and all required subsurface mooring hardware via a subcontract with UH. The Microcats and Seacats measured temperature and conductivity; four Microcats also measured pressure.

Table 5-3 provides the deployment information for each C-T instrument on the WHOTS-5 mooring.

SN:	Instrument	Depth	Pressure SN	Sample Interval (sec)	Start Logging Data(GMT)	Ice Bath In (GMT)	Ice Bath Out (GMT)	Time in Water (GMT
1099	Seacat	15	N/A	600	05/19/08 0:00:00	05/19/08 23:59:00	05/20/08 0:34:00	06/04/08 19:02:00
1085	Seacat	25	N/A	600	05/19/08 0:00:00	05/19/08 23:59:00	05/20/08 0:34:00	06/04/08 18:58:00
1087	Seacat	35	N/A	600	05/19/08 0:00:00	05/19/08 23:59:00	05/20/08 0:34:00	06/04/08 18:49:00
3381	Microcat	40	N/A	150	05/19/08 0:00:00	05/20/08 0:39:00	05/20/08 1:19:00	06/04/08 18:45:00
4663	Microcat	45	N/A	150	05/19/08 0:00:00	05/20/08 0:39:00	05/20/08 1:19:00	06/04/08 18:41:00
2530	1200 kHz ADCP	47.5	N/A	600	5/31/2008 0:00:00	N/A	N/A	06/04/08 18:41:00
1088	Seacat	50	N/A	600	05/19/08 0:00:00	05/19/08 23:59:00	05/20/08 0:34:00	06/04/08 18:36:00
1090	Seacat	55	N/A	600	05/19/08 0:00:00	05/19/08 23:59:00	05/20/08 0:34:00	06/04/08 20:04:00
1092	Seacat	65	N/A	600	05/19/08 0:00:00	05/20/08 0:39:00	05/20/08 1:19:00	06/04/08 20:09:00
1095	Seacat	75	N/A	600	05/19/08 0:00:00	05/19/08 23:59:00	05/20/08 0:34:00	06/04/08 20:13:00
4699	Microcat	85	10209	180	05/19/08 0:00:00	05/20/08 0:39:00	05/20/08 1:19:00	06/04/08 20:16:00
1097	Seacat	95	N/A	600	05/19/08 0:00:00	05/19/08 23:59:00	05/20/08 0:34:00	06/04/08 20:19:00
2769	Microcat	105	2949	180	05/19/08 0:00:00	05/20/08 0:39:00	05/20/08 1:19:00	06/04/08 20:24:00
4701	Microcat	120	10211	180	05/19/08 0:00:00	05/20/08 0:39:00	05/20/08 1:19:00	06/04/08 20:27:00
7637	300 kHz ADCP	125	N/A	600	5/31/2008 0:00:00	N/A	N/A	06/04/08 20:31:00
1100	Seacat	135	N/A	600	05/19/08 0:00:00	05/19/08 23:59:00	05/20/08 0:34:00	06/04/08 20:35:00
4700	Microcat	155	2479944	180	05/19/08 0:00:00	05/20/08 0:39:00	05/20/08 1:19:00	06/04/08 20:38:00

Table 5-3: WHOTS-5 mooring Microcat deployment information.

	S/N 7637 300 kHz	S/N 2530 1200 kHz
Number of Depth Cells	30	17
Pings per Ensemble	40	120
Depth Cell Size	4 m	1 m
Time per Ensemble	10 min	10 min
Time per Ping	4 sec	2 sec
Time of First Ping	05/31/08, 00:00	05/31/08, 00:00
Time in water	06/04/08, 20:31	06/04/08, 18:41
Time out of water	07/15/09, 23:58	07/16/09, 00:36
Time of last ensemble	06/22/08, 07:50	07/16/09, 21:34
Number of ensembles	3,216	59,309
Depth (meters)	125 m	47.5 m

Table 5-4: WHOTS-5 mooring ADCP deployment and recovery information.

All instruments on the mooring were successfully recovered. Most of the instruments had some degree of biofouling, with the heaviest fouling near the surface (e.g. Fig. 5-8). Fouling extended down to the ADCP at 125 m, although it was minor at that level (Fig. 5-9).

Figure 5-5 gives the post-deployment information for the C-T instruments. All instruments except Seacat SN 1097 returned full data records. The Seacat SN 1097 data record was almost empty. The Seacat SN 1087 conductivity sensor suffered an offset in late November 2008, and the Seacat SN 1095 temperature sensor failed soon after deployment.

With the exceptions noted above, the data recovered from the C-T instruments appear to be of high quality, although post-deployment calibrations are required. Figures A1-A14 (Appendix A) show the nominally calibrated temperature, conductivity and salinity records from each instrument, and pressure for those instruments that were equipped with pressure sensors.

Depth (meters)	Seabird Serial #	Time out of water	Time of Spike	Time Logging Stopped	Samples Logged	Data Quality	File Name raw data
15	Seacat 1099	7/16/2009 01:30	07/16/2009 05:08:00	07/16/2009 22:56:00	61,050	good	whots5_s_1099.hex
25	Seacat 1085	7/16/2009 01:39	07/16/2009 05:08:00	07/16/2009 09:43:00	60,971	good	whots5_s_1085.hex
35	Seacat 1087	7/162009 01:44	07/16/2009 05:08:00	07/16/2009 17:51:00	61,020	C offset in Nov '08	whots5_s_1087.hex
40	Microcat 3381	7/16/2009 01:47	07/16/2009 06:06:00	07/16/2009 09:46:00	233,016	good	whots5_m_3381.asc
45	Microcat 4663	7/16/2009 01:50	07/16/2009 06:06:00	07/16/09 23:07:00	233,016	good	whots5_m_4663.asc
50	Seacat 1088	7/16/2009 00:32	07/16/2009 05:08:00	07/16/2009 06:18:00	60,950	good	whots5_s_1088.hex
55	Seacat 1090	7/16/2009 00:28	07/16/2009 05:08:00	07/16/2009 09:52:00	60,972	good	whots5_s_1090.hex
65	Seacat 1092	7/16/2009 00:23	07/16/2009 06:06:00	07/16/2009 23:02:00	61,051	good	whots5_s_1092.hex
75	Seacat 1095	7/16/2009 00:20	07/16/2009 05:08:00	07/16/2009 06:12:00	60,950	Bad T	whots5_s_1095.hex
85	Microcat 4699	7/16/2009 00:13	07/16/2009 06:06:00	07/16/2009 09:20:00	190,650	good	whots5_p_4699.asc
95	Seacat 1097	7/16/2009 00:08	07/16/2009 05:08:00	07/16/2009 09:41:00	211	No in-water data	whots5_s_1097.hex
105	Microcat 2769	7/16/2009 00:05	07/16/2009 06:06:00	07/16/2009 09:15:00	190,650	good	whots5_p_2769.asc
120	Microcat 4701	7/16/2009 00:01	07/16/2009 06:06:00	07/16/2009 09:23:00	190,650	good	whots5_p_4701.asc
135	Seacat 1100	7/15/2009 23:53	07/16/2009 05:08:00	07/16/2009 17:56:00	61,020	good	whots5_s_1100.hex
155	Microcat 4700	7/15/2009 23:47	07/16/2009 06:06:00	07/16/2009 18:12:00	190,650	good	whots5_p_4700.asc

Table 5-5: WHOTS-5 mooring Seacat and Microcat recovery information.

Table 5-4 gives the post-deployment information for the ADCPs. The 300 kHz ADCP failed soon after deployment and returned a short data record. The 1200 kHz ADCP returned a full data record. The fouling on the 300 kHz ADCP transducer head at 125 m (Fig. 5-9) was minimal. The transducer faces for the 1200 kHz ADCP at 47.5 m were treated with an antifouling compound and consequently did not show any significant fouling (Fig. 5-8).

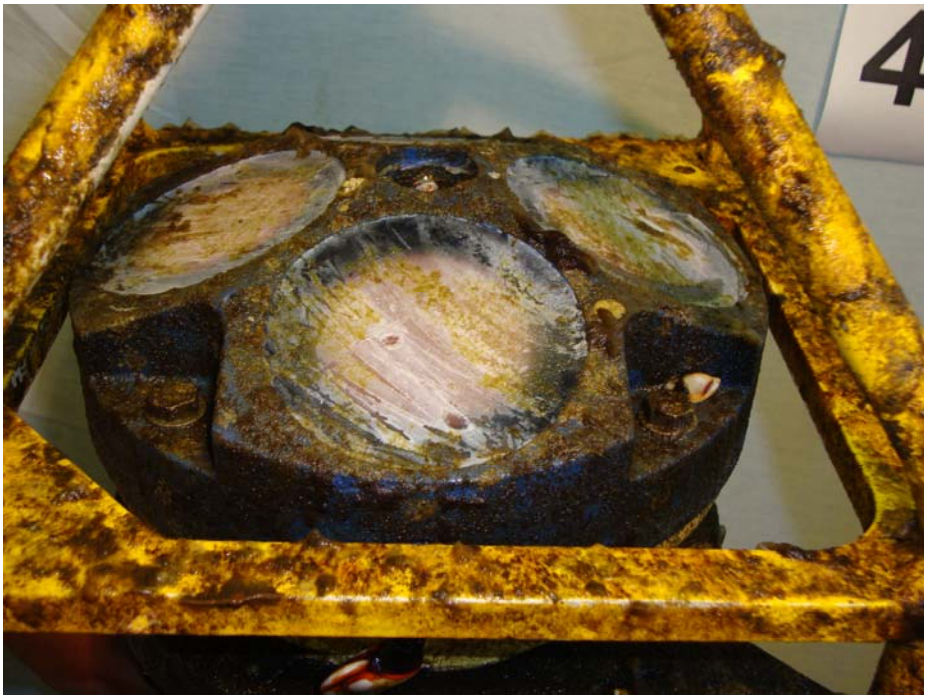

Figure 5-8: WHOTS-5 1200 kHz ADCP deployed at 47.5 m, after recovery.

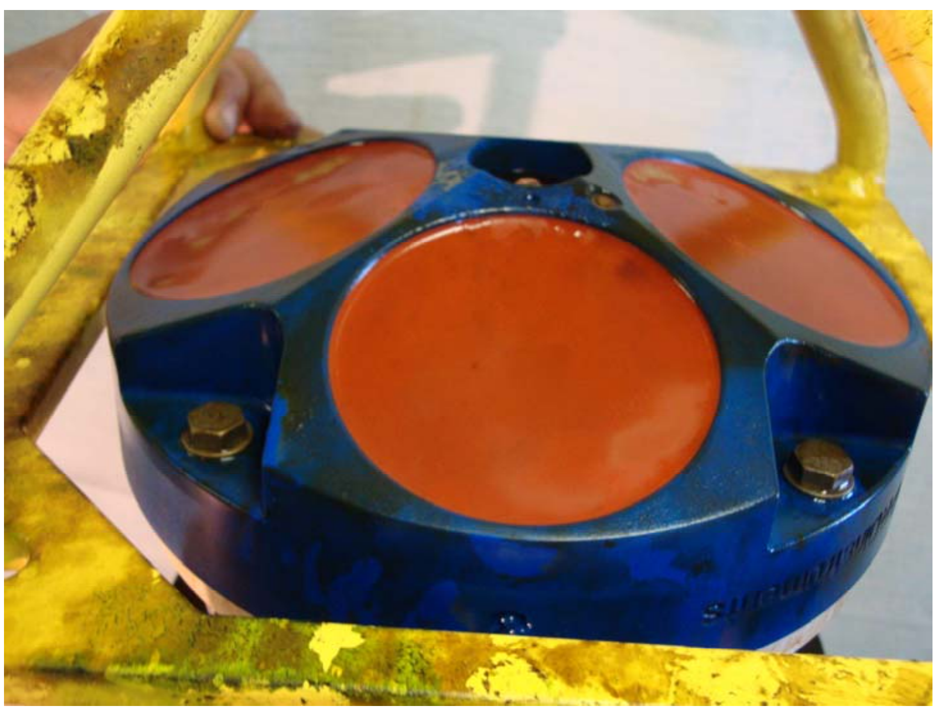

Figure 5-9: WHOTS-5 300 kHz ADCP deployed at 125 m, after recovery showing only minor fouling.

The 300 kHz ADCP was not pinging when recovered. The external battery pressure case was disconnected and its voltage was found to measure zero. The external battery underwater housing end-cap was removed carefully and high internal pressure was evident as the housing released a large amount of gas when the O-ring seal was opened. There was no indication of water inside the pressure housing, and there were no dry salt crystals present. Both battery packs were severely corroded with brown liquid trails observed on the upper battery pack plastic wrapping. This brown liquid is most likely the electrolyte from the battery cells, which consists of a concentrated aqueous solution of potassium hydroxide. The electrolyte eventually dripped down to the lower battery pack, shorting it where the power wire is connected to the battery pack. High temperatures were certainly experienced on both battery packs as severe charring was present. It is hypothesized that one or more cells in the upper battery pack failed, venting hydrogen gas which caused the leakage of electrolyte. This leakage started a chain event, destroying both batteries. It is uncertain why one or more of the cells failed, possibly from a poorly constructed cell, or a cell which started to discharge more rapidly than the others. A cell that is discharged below a safe cutoff voltage will also vent, resulting in electrolyte leakage. The University of Hawaii is working closely with RDI to try to determine the cause of the battery pack failure. The ADCP pressure case was subsequently opened and after finding no problems, communication was established with the instrument. The internal clock was offset by 1 minute 4 seconds ahead of GMT. It appears that the ADCP functioned for approximately 22 days although it was actually deployed 6 days after logging was initiated. Data collected during this brief time indicate that there may be some other problems, as it appears that there are gaps in the data resulting from rejection by the ADCPs internal diagnostics in greater amounts than seen in previous deployments using the same instrument. Where data exists, the range of the ADCP is approximately 90 m from the transducer head which is normal for this instrument.

Figure 5-10 shows the heading, pitch and roll from the short record from this instrument. Pitch and roll are generally less than 5 degrees from the vertical, but there are some periods with deviations from the vertical of as much as 10 degrees. Figure 5-11 shows the variations of the horizontal and vertical components of velocity in depth and time. The acoustic returns from the upper 40 m of the water column are intermittent, due to very low levels of scattering material near the surface. Diurnal migration of plankton often allowed good data returns from near the surface at night, however. The high spurious speeds due to sideband reflections near the surface are apparent.

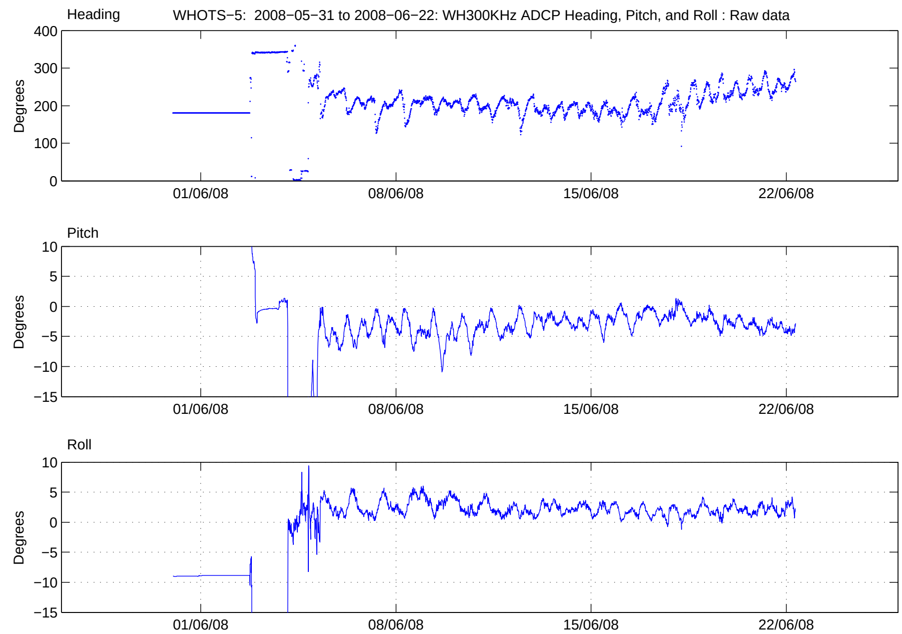

Figure 5-10: Heading, pitch and roll variations measured by the ADCP at 125 m depth on the WHOTS-5 mooring.

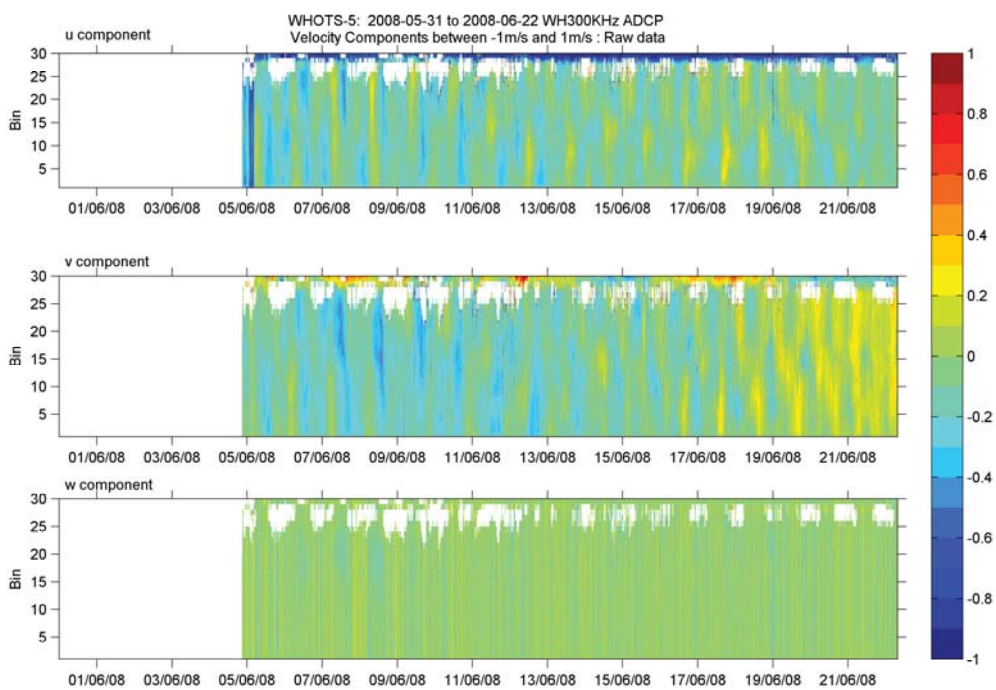

Figure 5-11: Time-series of eastward, northward and upward velocity components versus bin number measured by the ADCP at 125 m depth on the WHOTS-5 mooring. Height in meters above the transducer is approximately 4 times the bin number.

The data from the upward-looking 1200 kHz ADCP at 47.5 m appears to be of high quality. The internal clock was offset by 1 hour 13 minutes 34 seconds ahead of UTC, which seems abnormally high. Further examination of the record revealed that the ensemble time jumped from 09:30:00.00 to 10:33:59.59 between ensembles 5818 and 5819 (see **Error! Reference source not found.**). This offset in clock time seems to have propagated from this point forward to the end of the record. Prior to cancelling data acquisition the timing of the pings were checked against UTC. Pings were recorded to commence at 20:10:26 and end at 20:14:24. This leads us to suspect that the time stamp has somehow been corrupted and not the timing of the instrument. Table 5-6 summarizes events during the deployment.

Time of first ensemble	31-05-2008 00:00:00.00
ADCP in water time from deck log	04-06-2008 18:41:00.00*
Time of first velocity profile	04-06-2008 18:40:00.00
Time of ensemble 5818	10-07-2008 09:30:00.00
Time of ensemble 5819	10-07-2008 10:33:59.59
ADCP on deck time from deck log	16-07-2009 00:36:00.00*
Time of last velocity profile	16-07-2009 01:43:59.59
Time of last ensemble	16-07-2009 21:33:59.59

- These times are taken from a timeserver or GPS aboard the ship. All other times are taken from the ADCP itself.

Table 5-6: Summary of ADCP events during the WHOTS-5 deployment.

Figure 5-12 shows the heading, pitch and roll information from the ADCP. Pitch and roll are generally less than 5 degrees from the vertical, but there are some periods with deviations from the vertical of as much as 10 degrees. The ADCP can be seen to make one rotation through the months of December 2008 and January 2009.

Figure 5-13 shows the variations of the horizontal and vertical components of velocity in depth and time. The number and size of the depth cells resulted in a maximum range of less than 20 m from the transducer. With the instrument located at 47.5 m side-lobe interference from the sea-surface was not an issue. Data during the first half of the deployment extend across the full depth range with gradually more gaps appearing in the depth cells furthest from the ADCP during the second half of the deployment. This is most likely due to a combination of bio-fouling on the transducer heads and weaker echo returns as a result of reduced power output due to battery fatigue. Ringing and contamination from reflection from nearby instruments do not seem to be present although this will be examined more thoroughly during data processing.

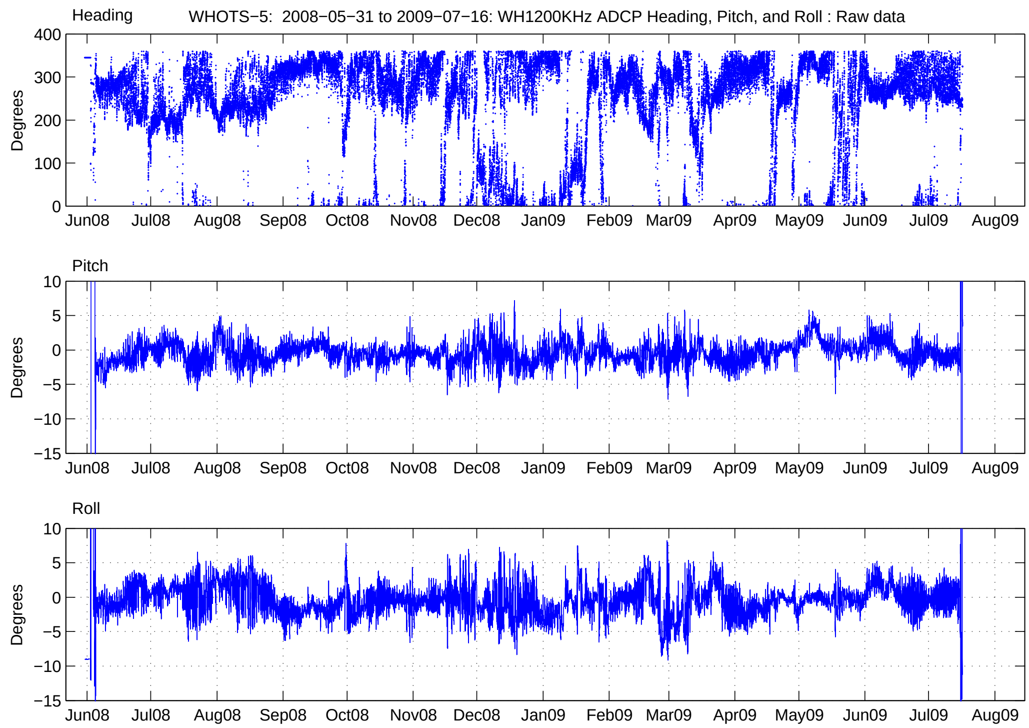

Figure 5-12: Heading, pitch and roll variations measured by the ADCP at 47.5 m depth on the WHOTS-5 mooring.

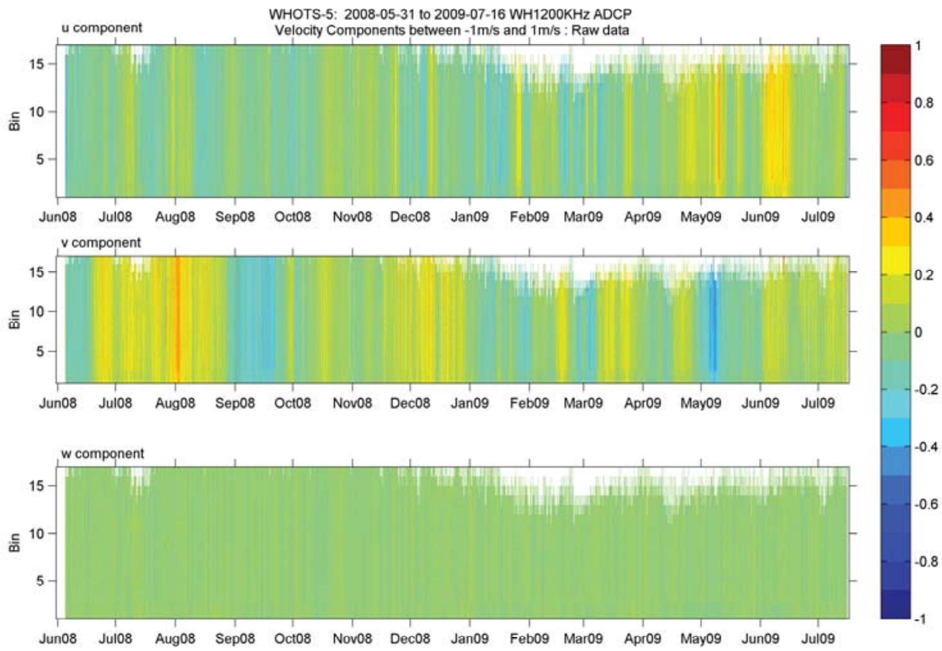

Figure 5-13: Time-series of eastward, northward and upward velocity components versus bin number measured by the ADCP at 47.5 m depth on the WHOTS-5 mooring.

6. CTD Operations

UH provided CTD and water sampling equipment, including a Seabird 9/11+ CTD sampling pressure, dual temperature, dual conductivity and dual oxygen sensors at 24 Hz. Seabird sensors used by UH routinely as part of the Hawaii Ocean Time-series were used to more easily tie the WHOTS cruise data into the HOT CTD dataset. The CTD was installed inside a twelve-place General Oceanics rosette with six 5-liter Niskin sampling bottles controlled by a Seabird carousel.

Station/cast	Date	Time (GMT)	Location	Maximum pressure (dbar)
52 / 1	7/11/09	16:02	22° 40.62´ N, 157° 59.32´ W	1020
52 / 2	7/11/09	19:55	22° 40.61´ N, 157° 58.94´ W	500
52 / 3	7/11/09	23:52	22° 40.62´ N, 157° 58.97´ W	500
52 / 4	7/12/09	03:52	22° 40.63´ N, 157° 58.98´ W	500
50 / 1	7/13/09	15:55	22° 46.51´ N, 157° 55.95´ W	500
50 / 2	7/13/09	19:53	22° 46.64´ N, 157° 55.94´ W	200
50 / 3	7/13/09	20:18	22° 46.65´ N, 157° 55.94´ W	500
50 / 4	7/13/09	23:53	22° 46.96´ N, 157° 55.63´ W	500
50 / 5	7/14/09	03:55	22° 46.62´ N, 157° 55.78´ W	500
2/1	7/16/09	22:03	22° 45.01´ N, 158° 00.00´ W	4808

Table 6-1: CTD stations occupied during the WHOTS-6 cruise.

A total of 10 CTD yo-yo casts were conducted at stations 52 (near the WHOTS-6 buoy), at station 50 (near the WHOTS-5 buoy), and at station 2 (at the HOT site). The first cast was to a depth of 1000 m for the purpose of calibrating the CTD conductivity cells. Four CTD casts were conducted to obtain profiles for comparison with subsurface instruments on the WHOTS-6 mooring after deployment, and 5 more casts were conducted for comparison with the WHOTS-5 mooring before recovery. These were sited approximately 0.25 to 0.5 nm from the buoys. The comparison casts each consisted of 5 yo-yo cycles between 5 dbar and 200 dbar, with the last cycle up to 200, 500 or 1020 dbar (see Table 6-1). Station 50 cast 2 had only one yo-yo cycle because the winch operator inadvertently took the CTD out of the water at the end of the first cycle and the cast was terminated. One near-bottom cast was conducted at station 2 for troubleshooting two temperature sensors, and to obtain a full-depth profile. Station numbers were assigned following the convention used during HOT cruises. Station 50 is the nominal site of WHOTS-1, -2, -3, and -5, and station 52 is the nominal site of WHOTS-4, and -6. Table 6-1 provides summary information for all CTD casts, and Figures B1-B19 (Appendix B) show the water column profile information that was obtained.

Water samples were taken from all casts except station 50 cast 2; 6 samples for 1020 dbar and 4808 dbar casts, and 2 to 3 samples each for the 500 dbar casts. These samples will be analyzed for salinity and used to calibrate the CTD conductivity sensors.

7. Thermosalinograph

The *Kilo Moana* has an Uncontaminated Scientific Sea Water (USSW) system that includes an internal Seabird Micro-Thermosalinograph (TSG) model SBE-45, with an SBE-38 digital remote temperature sensor. The seawater intake is located on the starboard hull, 20'8" from the bow, at a mean depth of 8 m. The remote temperature sensor is installed in the bow thruster chamber approximately 2–3 m from the seawater intake. The pump that draws water through the system is situated between the intake and the remote temperature sensor and consequently remote temperature data are affected by warming due to the pump. An offset correction is made to the final data by comparing the remote temperature data with 8 dbar CTD data. The mean temperature difference from the CTD casts conducted during the cruise was 0.25°C. The internal TSG is located in the IMET lab on the port side of the ship. Sensor information for the TSG system during WHOTS-6 is as follows:

Temperature: SBE-38 Sensor SN 0169 was used to measure temperature near the seawater intake, and was last calibrated on December 12, 2008, and installed on May 20, 2009. The SBE-45 thermosalinograph used temperature sensor SN 0267, which was last calibrated on October 09, 2008, and installed January, 2009.

Conductivity: The SBE-45 thermosalinograph used conductivity sensor SN 0267, which was most recently calibrated on October 09, 2008, and installed January, 2009.

Water samples were drawn from an intake located about 2 m from the thermosalinograph system every 8 hours during the cruise for post-calibration of that dataset. The TSG data are shown in Figures C1-C8 (Appendix C).

8. Shipboard ADCPs

The R/V *Kilo Moana* is equipped with an RD Instruments 300 kHz Workhorse Mariner ADCP and an RD Instruments Ocean Surveyor 38 kHz ADCP. The University of Hawaii ADCP processing system is installed, producing real-time profiles and other products. In addition to providing an intercomparison with the upward-looking ADCPs on the WHOTS moorings, the shipboard ADCP systems revealed interesting regional current features as shown in Figure 8-2.

During the WHOTS-6 cruise, Station ALOHA was under the influence of the eastern North Pacific high pressure system, and subject to moderate easterly trade winds (Figure 8-1). An upper level trough extended from the northeast of ALOHA towards the southwest, slightly destabilizing the lower atmosphere. This resulted in somewhat greater vertical development of trade wind cumulus, and occasional light rainfalls.

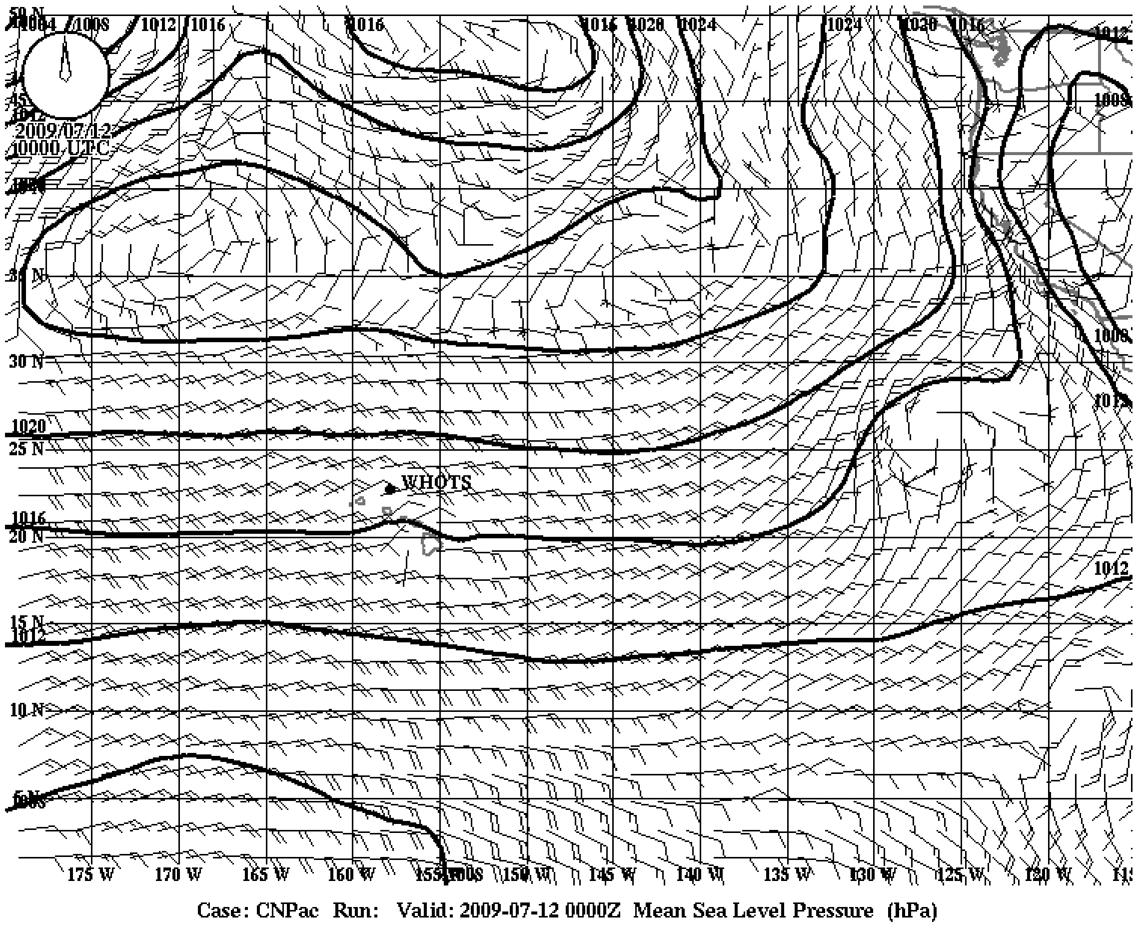

Figure 8-1: The NOAA/NCEP GFS surface wind and sea level pressure analysis for the central-eastern North Pacific, valid for 0Z on July 12, 2009.

The near surface (27 m) currents were eastward near Oahu (Figure 8- 2). The Hawaiian Ridge Current was evident, with north-northwestward flow between Oahu and ALOHA. At Station ALOHA, the currents veered from northwest to northeast, as an anticyclonic eddy to the east of ALOHA drifted westward (Figure 8-3). The currents were also influenced by M2 internal tides and by inertial waves (Figure 8-4).

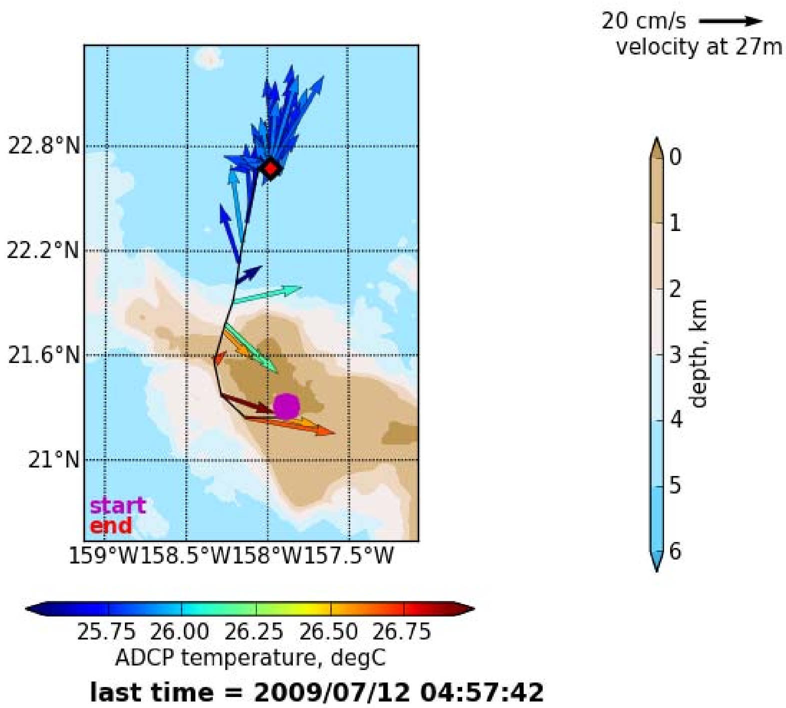

Figure 8-2: Shipboard 300 kHz ADCP currents from July 9-12, 2009 at a depth of 27 m. The currents at Station ALOHA veered from northwestward to northeastward over the 3 days on station.

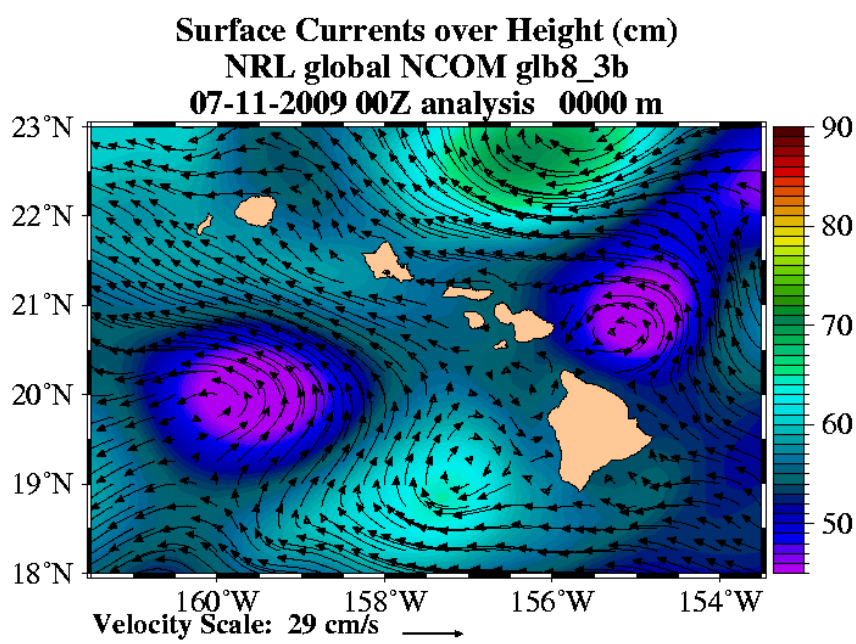

Figure 8-3: Surface currents (vectors) overlaid on sea surface height anomaly (colors) from the Naval Oceanographic Office NCOM analysis for 0Z on July 11, 2009.

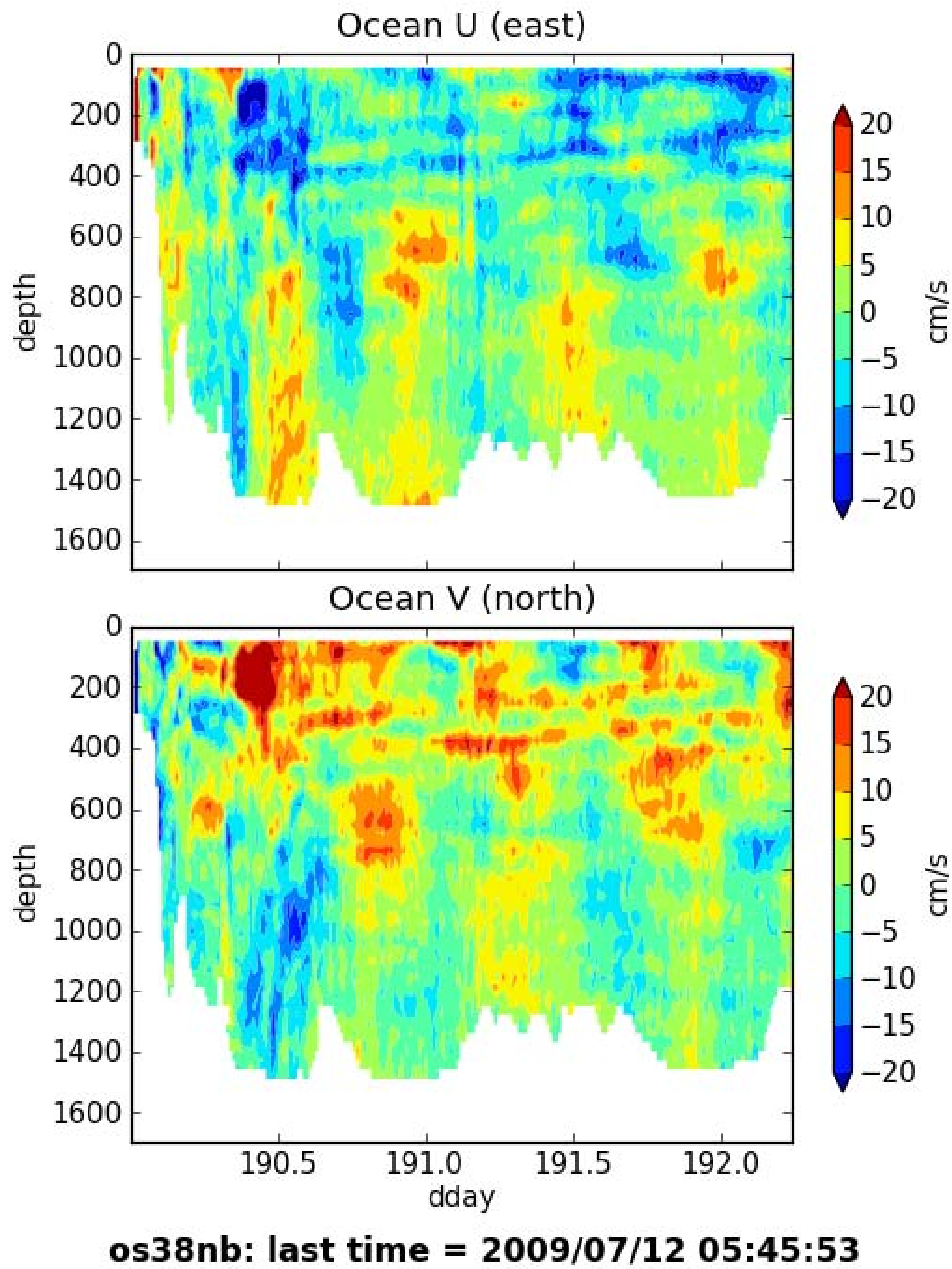

Figure 8-4: Shipboard 38 kHz ADCP currents from July 9-12, 2009 as a function of depth and time. Inertial waves can be seen as upward trending, but nearly horizontal, maxima and minima in the velocity components. The M2 internal tides can be seen as the nearly vertically aligned maxima and minima in the velocity components.

9. WHOTS-6 Meteorological Comparisons

The *Kilo Moana* was heavily equipped with meteorological instrumentation for three separate, but inter-related purposes:

1. The regular ship/buoy intercomparisons which are carried out at the time of WHOI buoy turnaround;

2. Validation of the ship's suite of meteorological instruments against independent sets of instruments;

3. Continuing investigation, and hopefully resolution, of past inconsistencies in calibration and performance of short-wave pyranometers.

This report describes the set-up on the ship, the procedures adopted, and some preliminary, and necessarily incomplete, results from analyses during the cruise and deployment. Detailed results from each of these three projects will be reported in due course, after retrieval of some internally recorded data and further analysis.

Ship's instruments

The *Kilo Moana's* meteorological instruments are located on a tower extending some 6-7 metres above the wheelhouse roof, at a height of 20.7 metres above the waterline. They consist of two anemometer/wind vanes, a Rotronics air temperature/humidity unit (T/RH), a separate air temperature sensor (Resistive Temperature Device; RTD), one each of siphon and optical raingauges, and a pair of Eppley longwave (PIR) and shortwave (PSP) radiometers.

The platform on which the radiometers are mounted has been raised by about half a metre since the previous WHOTS cruises, to reduce shadowing from other instruments. It is also on the starboard side of the tower, which has the better exposure with the ship headed east into the trade winds. Both temperature instruments are mounted in fan ventilated shields. However, it was found that neither fan was actually working.

Signals from these sensors are recorded on a logger situated on the tower, converted into physical units (with the exception of the radiometers) and made available continuously on the ship's network with files closed daily (GMT).

Other instruments required for the intercomparison project are the barometer, which is located 4.8 metres above waterline in a laboratory near the after deck, and the ship's thermosalinograph. This takes water in through an inlet port 8m deep on the starboard hull, and pumps it across to the measuring instrument in the port hull. Two temperatures are provided.

WHOI AutoIMET

AutoIMET is a portable self-contained package of meteorological instruments and loggers designed by WHOI. On this cruise a package of freshly calibrated sensors was installed alongside the ship's instruments on the tower. They comprised a PIR and PSP pair of radiometers, a T/RH unit in a "beehive" naturally ventilated shield, a barometer and a siphon raingauge. Because the tower was becoming crowded with wind sensors (2 ship propeller/vane units and one PSD sonic) the AutoIMet wind sensor was mounted on the rail above the wheelhouse at 17m above the waterline. The front of the ship presents a massive obstruction to the wind, and it was hoped that this move would provide more information on the wind distortion in speed and direction.

The AutoIMET records data internally at one sample per second, which is available after the system is returned to WHOI. However, 2-second data was transmitted to a computer connected to the ship's network, and daily files were accessible to users for real-time monitoring,

PSD system

The PSD system is the "portable standard" funded by NOAA/OceanObs as part of the SAMOS initiative, in which the regular meteorological equipment on research vessels is to be maintained at a performance level such that bulk air-sea fluxes of momentum, heat and moisture may be obtained for use in climate research. The portable standard was developed to monitor the performance of any ship's system. It is a self-contained package comprising high-quality sensors for all the meteorological variables, including a fast response sonic anemometer and humidiometer for direct measurement of the fluxes. The sensors are mounted on a 10m lattice tower, and the supporting equipment is in a custom-designed container.

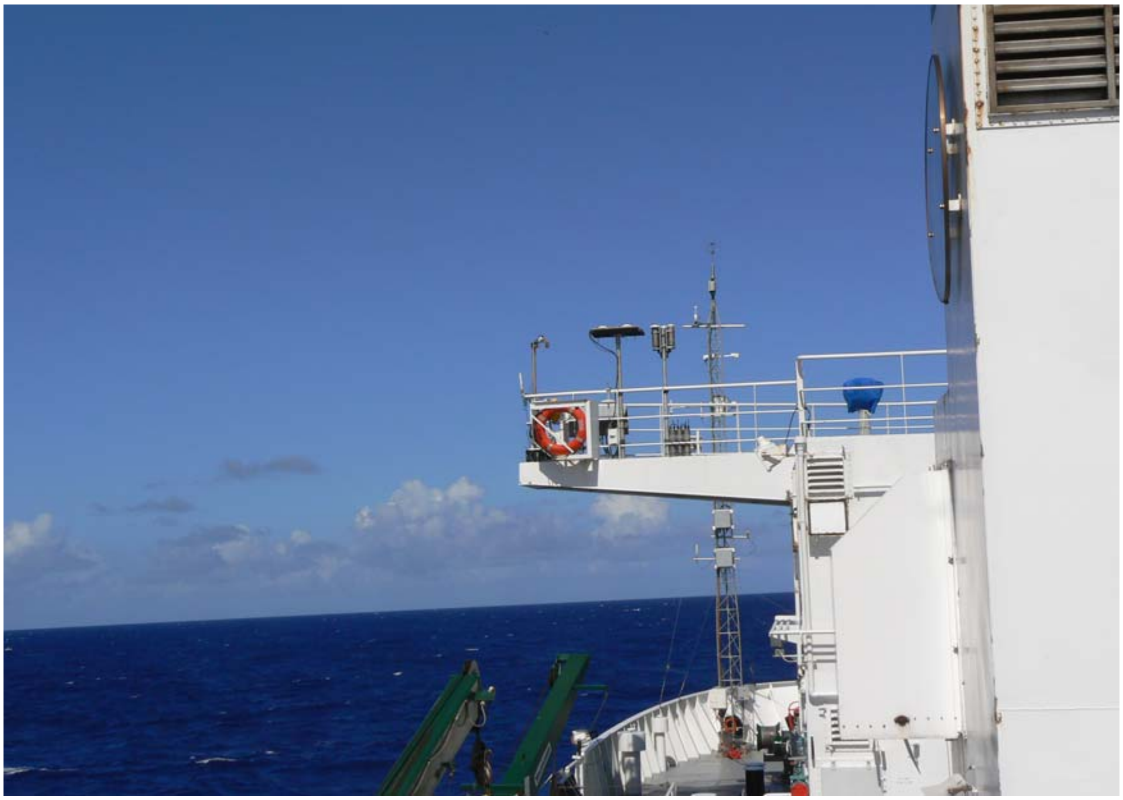

Figure 9-1: PSD instrument tower, partly obscured by the port bridge wing, which holds some of the radiometers deployed for the comparison project.

For the WHOTS-6 cruise the tower was mounted forward on the port hull, and the container was further aft on the 01 deck with wireless connection between them. Figure 9-1 is a view of the tower from the location of the container. The sonic was at a height of about 16.5m above the waterline, and the Vaisala T/RH sensor in a ventilated shield at about 14m. SST was measured with a "Seasnake" hung over the gunwale and floating at a depth of between 5 and 10 cm, between the hulls. The PSD radiometers were mounted on the port bridge wing to enable their inclusion in the radiometer comparison (project #3 above).

Radiometers

Instruments for the radiometer comparison were deployed in four locations; the PSP/PIR pairs associated with the ship and AutoMET systems were on the main tower as described above; each buoy had two PSP/PIR pairs which were included in the respective ship/buoy intercomparisons; and Figure 9-1 shows several more mounted on the port bridge wing. A close-up of this group is shown in Figure 9-2.

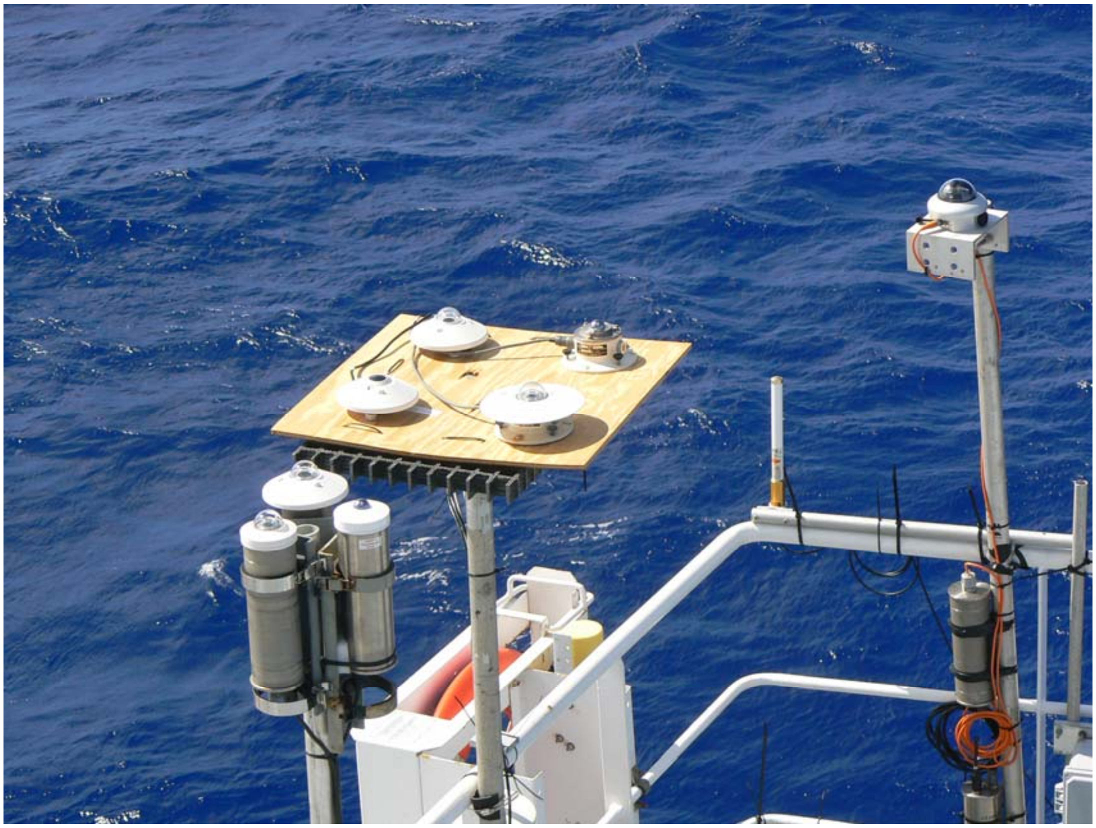

Figure 9-2: Radiometers on the port bridge wing.

Two pairs of PSP/PIR mounted on the wooden board are part of the PSD system. The separate group of 3 consists of a pair of WHOI standard (Eppley) PSP and PIR, and a Kipp and Zonen CMP22 shortwave radiometer (with the heat shield). The lone instrument is a Delta SPN1 combined direct/diffuse radiometer (described in the Stratus 8 cruise report UOP TR 2008-01). The lean on the SPN1 pole is so that the actual instrument is level. These radiometers are at a height of about 14.4m above the waterline.

Intercomparisons

Having deployed WHOTS-6 and surveyed the anchor position, the ship maintained position about 0.15 nm downwind of this mooring, beginning the intercomparison at about 0500 GMT on 11-July (Day 192) until 1000 GMT on 13-July (Day 194). At this time, the ship moved to a similar position downwind of WHOTS-5 for two days of intercomparison before recovering it. The intercomparison period began at about 1145 GMT on 13-July (Day 194) and ended at 1500 GMT on 15-July (Day 196). Throughout the four intercomparison days, the wind was a steady easterly at 7-9 ms^{-1} with scattered cloud. Both buoys were blown westward about 3.3km from their anchor location.

A detailed, quantitative analysis of the results of the meteorological comparisons between the ship, AutoIMET, PSD and the two buoys will be reported separately, with particular emphasis on the shortwave radiometer question. Here we only describe some noteworthy features of instrument performance which were obvious from preliminary graphs of time series. We include one or two examples of these time series to indicate some characteristics of the data available at this stage. In what follows, Buoy 6_7 and Buoy 6_19 refer to the loggers 7 and 19 on WHOTS-6, and similarly for Buoy 5_9 and 5_10 on WHOTS-5.

Air Temperatures

Figure 9-3 shows temperature records on Day 194 from all the sensors. This was the day when the ship moved from the WHOTS-6 location to WHOTS-5. So the left side of the graph (to about Day 194.4 GMT) shows comparisons with the freshly deployed buoy, and the right-hand side comparisons with the "old" buoy. The shortwave radiation trace is included to indicate local daytime. Both days were almost completely clear, a situation which will greatly benefit our SW radiometer study. Even these preliminary records reveal a number of important features.

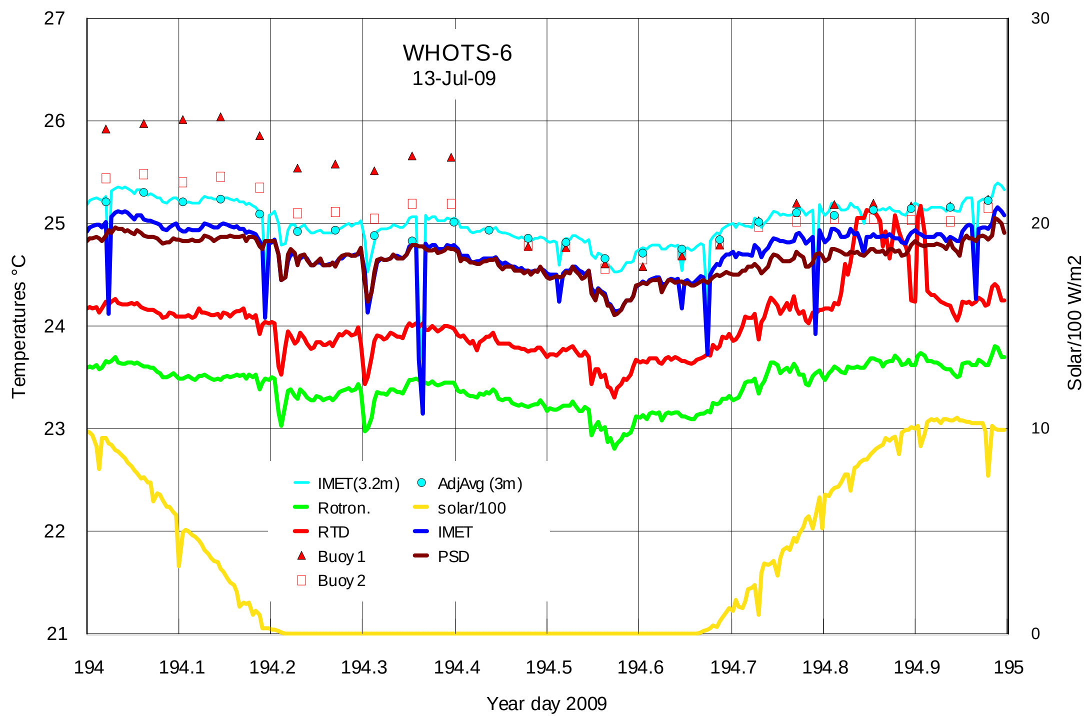

Figure 9-3: Air temperatures from 2 ship sensors (red and green), AutoIMet (blue), and PSD (brown). Pale blue is the IMET adjusted down to 3.2m, and hourly averaged (pale blue dots) for comparison with the buoy sensors (1 and 2). WHOTS-6 is on the left of Day 194.4, and WHOTS-5 on the right.

The ship and AutoIMET meteorological sensors were at roughly the same level (~20m above the waterline) so may be compared without height adjustment. In the two previous years the ship's temperature sensors were found to read between 0.5ºC and 1.5ºC low compared with other instruments. This was found to be still the case this year. The RTD was systematically about 0.8ºC lower than IMET, and the temperature from the Rotronic T/RH unit tracked about

1.3ºC lower. Between 194.8 and 194.9 the RTD was being examined and the ventilator fan found to be not working. However, such a large discrepancy is unlikely to be associated with the failure of the ventilator fans, and it's being investigated by the ship's Technical Group. Significantly, the Rotronic RH measurement was within 2% of the other instruments, which seems to rule out a problem with the ship's logger.

The PSD T/RH unit was in an aspirated shield at a height of about 14m above the waterline. A strict comparison between IMET and PSD would require one or the other to be height adjusted, but at this elevation the adjustment is too small to show up on the graph. The two temperatures agree well at night, but IMET reaches about 0.2ºC higher in day inside its naturally ventilated shield. Despite strong solar radiation, the 8 ms^{-1} wind limited heating. Spikes in the IMET record are spurious and likely associated with the improvised 2-min data monitoring software. They are unlikely to exist in the 1-minute recorded data.

Agreement between height-adjusted IMET and both sensors on WHOTS-5 is excellent, particularly after a year of unattended operation. We were aware at the dock of the anomalously high reading of one WHOTS-6 sensor (~0.6ºC), but despite extensive investigation, the cause could not be found.

Relative Humidity (RH)

The RH time traces from IMET, PSD, and the ship follow one another closely within an envelope about 3% wide. Generally IMET is on the high edge of the envelope and the ship on the lower edge with PSD in between. For these sensors, this must be regarded as very satisfactory agreement. Adjustment of IMET down to 3.2m height increases RH by about 6%. The hourly values of all four buoy sensors are generally between 2% and 5% below the IMET hourly average.

Wind speed and Direction

Wind speed and direction are the two most variable quantities of those we need to measure, both in time-scale and magnitude. Even in the fairly steady trade wind, gusts and lulls can change speed by a factor of two and direction by 30 degrees in a matter of seconds. Only the most general information can be gleaned from a graphical wind record, especially when anemometers are subject to flow distortion (as on board ship). With this qualification, it can be said that the two ship propeller anemometers at a height of about 22m agreed well with one another and with the PSD sonic located beside them. The PSD sonic at the top of the lattice tower (about 18m above the water) read slightly less, and as expected the IMET propeller just above the bridge roof read about 0.5 ms^{-1} lower again.

From a speed around 7.5 ms^{-1} at 22m height, the ship wind speeds adjusted down to about 6.5 ms^{-1} at the height of the buoy propellers. One of the WHOTS-5 anemometers had failed. The other three measured slightly higher than the hourly-averaged height-adjusted values from the ship.

Sea Temperature

In last year's report the physical arrangement of the thermosalinograph system was explained. Referring to Figure 9-4, sea water is sucked in at 7m depth on the starboard hull, its temperature measured by a highly accurate sensor **after** the pump (red trace). It's piped across the air-conditioned ship to the thermosalinograph in the port hull,

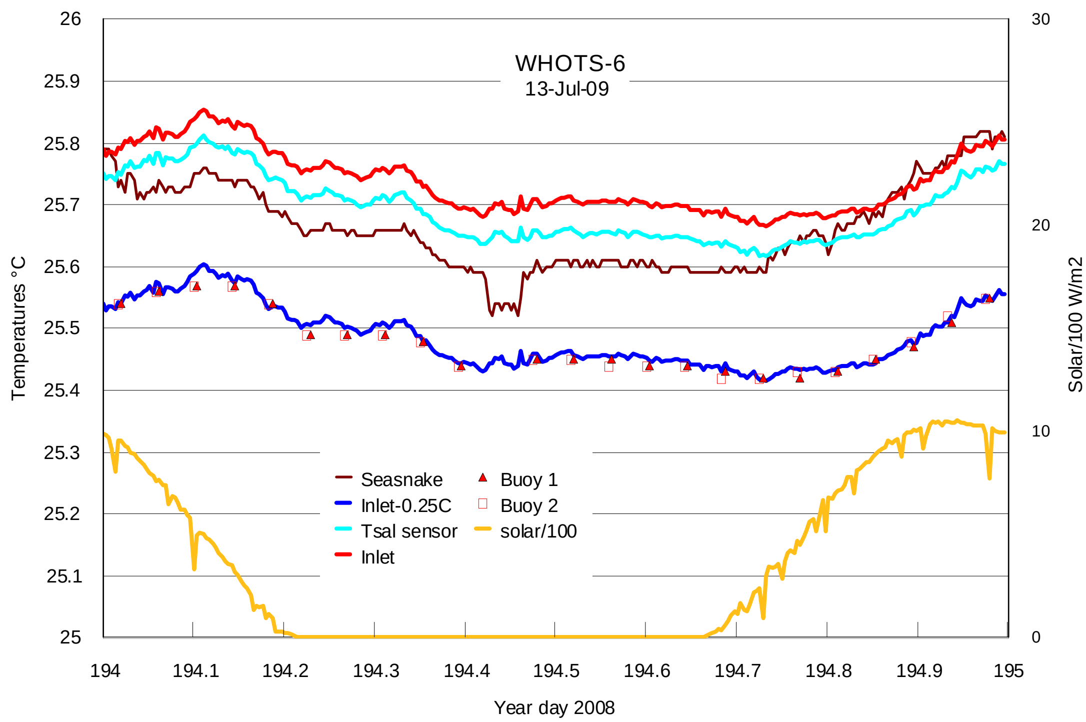

Figure 9-4: Sea temperature sensors. The period when the ship was steaming at 8 knots from WHOTS-6 to WHOTS-5 is clear in the Seasnake record, which probably spent some time airborne.

cooling as it goes (pale blue). At the end of the cruise a correction based on the cruise records of surface CTD is provided, courtesy of Fernando Santiago or Paul Lethaby. Last year the correction was -0.296ºC, and this year it was -0.25ºC (dark blue) probably due to a change of sensor. The sea temperature sensors on both buoys agree very closely with this, but there is some uncertainty about their effective depth. The PSD Seasnake (brown trace) appears to be unreasonably high in conditions when the surface water should be well mixed. Being close to the surface it does show evidence of diurnal warming. Thinking that the water between the hulls might be slightly warmed by the ship, the Seasnake was moved outboard of the port hull, but this made no difference.

Radiation (Longwave and Shortwave)

At the time of TOGA-COARE (1992) even the principle of operation of the longwave radiometer (the pyrgeometer) was not well understood. Disagreements between individual instruments ranged from 12 Wm^{-2} during the night to 50 Wm^{-2} during the day. Since that time, the pyrgeometer has been subjected to intensive study, and our methodology of calibration and use has improved to the point where Colbo and Weller (2009) estimate the fundamental uncertainty of the instrument to be about 4 Wm^{-2} for daily averages. During Stratus 8, three pyrgeometers showed instantaneous differences of less than 5 Wm^{-2} during the day and 3 Wm^{-2} at night. For the present cruise, eyeballing the comparisons between the Ship, PSD, IMET, WHOTS-5 and WHOTS-6 pyrgeometer traces, they are all clearly within an envelope of 5 Wm^{-2}.

Our problem now is with the shortwave radiometer performance. A 5% error at the diurnal solar peak in the sub-tropics can represent a 60 Wm^{-2} discrepancy in the net energy budget. The collection of recently calibrated pyranometers on this cruise, from two manufacturers and different calibration facilities, is designed to improve our methodology with shortwaye measurement in the same way that we have with longwave. This will be the subject of a separate report, but Figures 9-5 and 9-6 are an indication that we are making progress.

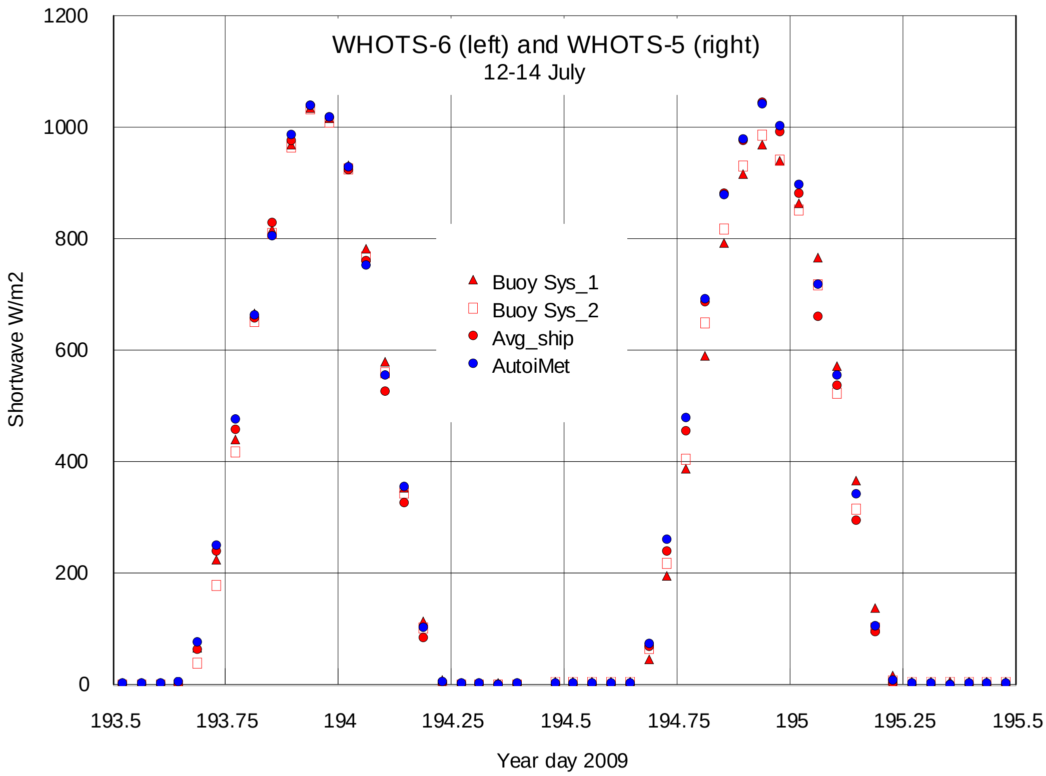

Figure 9-5: Hourly average values of solar radiation (Wm^{-2}) from PSPs on the Ship (red circle), IMET (blue circle), buoy pair (triangle and square). At Day 194.4 the ship moved from beside WHOTS-6 to beside WHOTS-5.

The last day of the intercomparison with WHOTS-6 and the first with WHOTS-5 were both almost completely clear. Without cloud the hourly averages dictated by the buoy data are easier to interpret. The result appears to support our hypothesis that instruments deployed before 2009 underestimated solar radiation by about 5%, for reasons yet to be determined.

Figure 9-6 is an expanded view through noon of the clearest day during the cruise. The Ship (red) and IMET (green) instruments are Eppley PSPs recently calibrated at Eppley and WHOI respectively. The PSD (blue) trace is the average of two instruments, an Eppley PSP and a Kipp and Zonen CMP22; the calibration history of these two instruments is not known at this stage, but is believed to involve a third calibration facility at the NOAA lab. in Boulder. The close agreement signifies that we are making good progress toward the resolution of uncertainties in shortwave measurement.

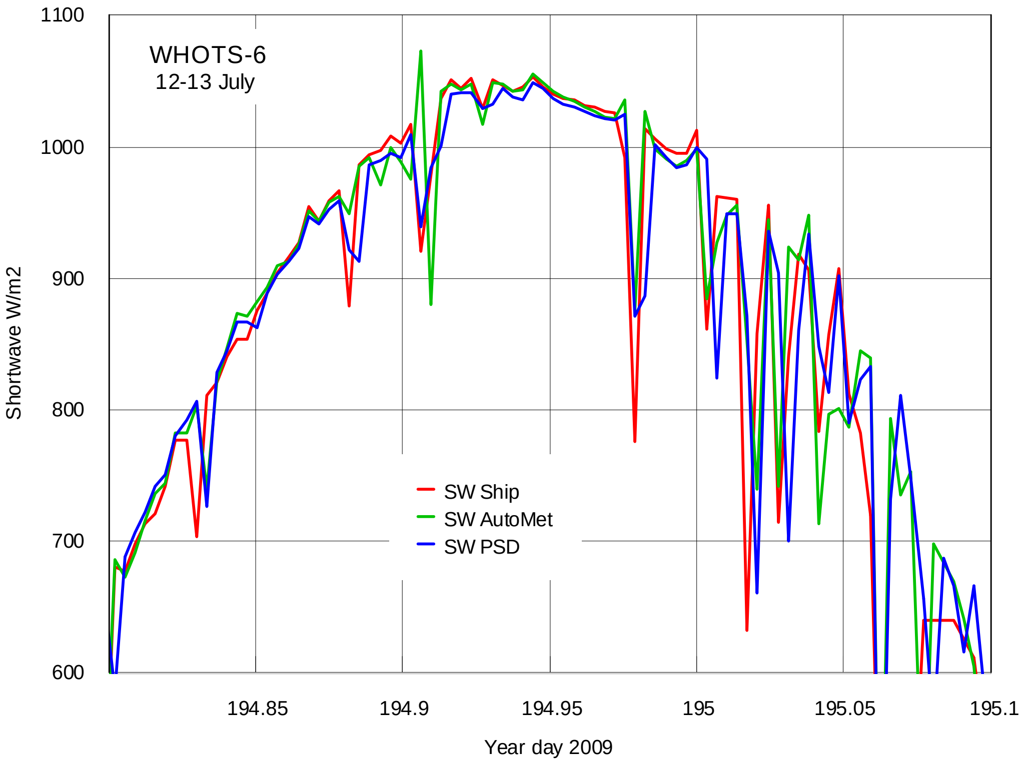

Figure 9-6: Comparison of shortwave radiometers on the R/V *Kilo Moana*.

10. PSD Flux Group

The Earth System Research Laboratory (ESRL) Physical Science Division (PSD) air-sea flux group collected surface meteorology, cloud, and rawinsonde observations during the Woods Hole Oceanographic Institution (WHOI) Hawaii Ocean Time-series Station (WHOTS) research cruise on board the University of Hawaii (UH) Research Vessel *Kilo Moana*. Instruments were deployed on the ship a few days prior the departure date.

a. Flux system

A 30' tower was setup on the 01 deck of the portside bow of the ship (Figures 10-1 and 10-2). The fast turbulence system installed on the bow tower is composed of a GILL Sonic anemometer, a Li-Cor LI-7500 fast CO_2/hygrometer, and a Systron-Donner motion-pak. A mean T/RH sensor in an aspirator and an optical rain gauge were also mounted on the bow tower. To complete the PSD air-sea flux system, pyranometers and pyrgeometers (Eppley and Kipp&Zonen) were mounted on top of pole on the 03 deck. Finally, a near surface sea surface temperature sensor ('sea snake') consisting of a floating thermistor was deployed from the portside pontoon. A second sonic anemometer was also deployed on the bridge mast.

Slow mean data (T/RH, PIR/PSP, etc) are digitized on two Campbell dataloggers and transmitted via wireless as 1-minute averages. Inside the operation van (deployed on the portside pontoon of the ship, 01 deck), a central data acquisition computer logs continuously all sources of data via RS-232 digital transmission and wireless radio modem network.

1. Sonic Anemometers (two sonics)
2. Licor 7500, CO2/H2O
3. Slow means (two Campbell dataloggers)
4. Systron-Donner Motion-Pak
5. GPS
6. Heading and pitch/roll systems (two Crescent VS100)

The 10 data sources are archived at full time resolution. At sea, a set of programs are run in order to read the sonic anemometers (acquired at 10 Hz) and the mean measurement systems (sampled at 0.1 Hz and averaged to 1 min), and write daily text files at 1 min time resolution. The 1-min daily ASCII files are named as *proc_nam_DDD.txt* (nam='pc', or 'son'; DDD=yearday where 000 GMT January 1, 2009 =1.00). File structure is described in the readme accompanying these files. Further data analysis will include time matching the PSD met data with the ship's various systems in order to create 5 and 30-min daily flux files.

Figure 10-1: View of the operation van deployed on 01 deck of the *Kilo Moana*. The bow tower can be seen on the background.

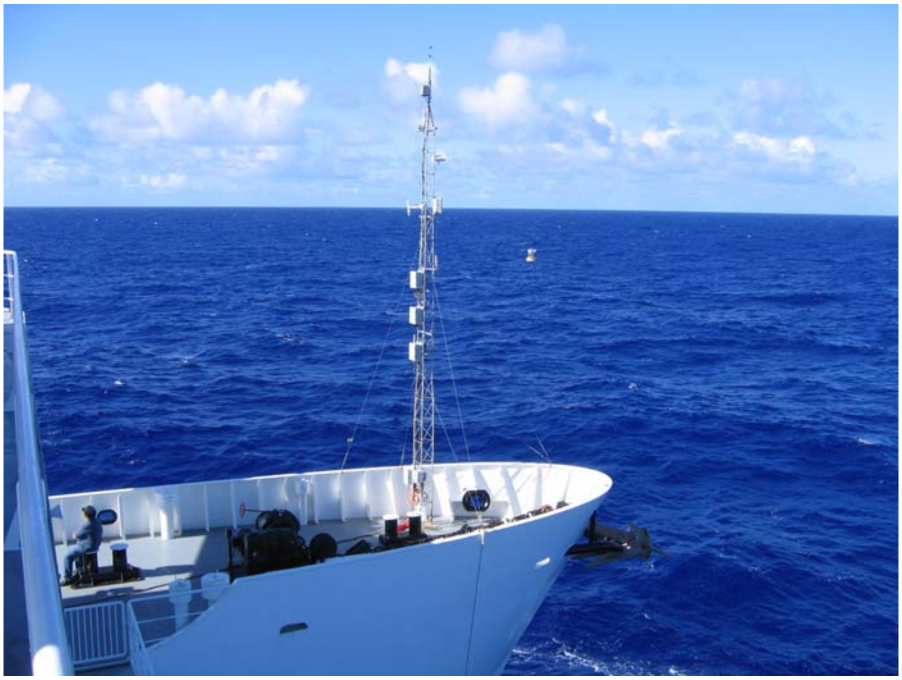

Figure 10-2: Flux tower deployed at the bow of the portside pontoon. The sea surface thermistor, i.e. ‘sea snake’, can be seen on the inboard side of the pontoon. It was moved on the outboard side later during the cruise.

b. ***CL31 cloud base ceilometers***

The ceilometer is a vertically pointing lidar that determines the height of cloud bases from time-of-flight of the backscatter return from the cloud. The instrument was setup in front of the operation van on the 01 deck (Figure10-3). The time resolution of the unit used during the WHOTS cruise is 30 seconds and the vertical resolution is 30 m. The raw backscatter profile and cloud base height information deduced from the instrument's internal algorithm are stored in daily files.

Figure 10-3: View of ceilometer and microwave radiometers at the operation van on 01 deck.

b. Microwave Radiometers

Two microwave radiometers (MWR) were deployed during WHOTS 2009 cruise (Figure 10-3). The two channel MWR (Mailbox) operates at 23.8 GHz and 31.4 GHz frequency, with a bandwidth of 0.4 GHz. The two channels allow one to retrieve water vapor (23 GHz) and liquid water path (31 GHz) estimate. A continuous automatic self-calibration developed by the Atmospheric Radiation Monitoring (ARM) program is implemented for this instrument. This MWR was configured to get the retrievals at 90 degrees elevation angle, with a sample resolution of 48 sec. The 90 GHz MWR is another system sensitive to liquid water path. Manual tip calibrations are required with this system but were not performed during that cruise due to the lack of adequate clear sky periods.

c. W-band cloud radar

The PSD W-band cloud radar operated during WHOTS was installed in the operation van (Figure 10-4). The vertically pointing antenna is mounted on a mechanically stabilized platform to take out the pitch and roll of the ship. The cloud radar can be used to deduce profiles of cloud droplet size, number concentration, liquid water concentration, etc. and thus characterize clouds in the region. If drizzle (i.e., droplets of radius greater than about 50 μm) is present in significant amounts, then the microphysical properties of the drizzle can be obtained from the first three moments of the Doppler spectrum. Table 10-1 describes the characteristics of the W-band radar.

Figure 10-4: View of the W-band radar inside the operation van.

Application	**Cloud Properties**
Frequency	94.56 GHz
Peak/Avg Power	1750/6W
Antenna (beamwidth)	12 in Cassegrain (0.73 deg)
Pulse Width	167ns
Range Cell Size	25 m
Number of Range Cells	198
Range	~0.1 – 4.9 km
Velocity Resolution	12.3 cms-1
Max Radial Velocity	± 7.9 ms-1
Antenna Beam Positioner	Pitch-Roll Compensation
Pointing Directions	Vertical
Signal Processing	Average FFT, 0.33 s dwell time
Sensitivity (est)	-31 dBz (R = 2km)
Power (estimate)	120 VAC @ 8 amps

Table 10-1: Radar Characteristics during WHOTS 2009.

e. Radiosondes

44 Vaisala RS92-SGP radiosondes were launched on the WHOTS 2009 cruise starting on July 10, 06:00 UTC, and every 6 hours thereafter until July 17, 09:00 UTC. Radiosondes sample the atmosphere every 1 s and transmit observations to a Vaisala MW21 ground receiver unit (setup in Lab#1 on the main deck, Figure 10-5). Helium gas was used to inflate the radiosonde balloons on the main deck (Figure 10-5). The radiosondes collect vertical profiles of temperature, relative humidity, pressure, and winds (calculated from GPS).

Figure 10-5: Left panel: view of the inflation site on the main deck with the Helium bottles on the 02 deck. Right panel: Vaisala radiosonde system deployed in Lab#1 of the Main deck.

f. Data Archive

Selected data products were made available at the end of the cruise for the joint cruise archive. Further analysis will be done in order create the 5-min and 30-min daily flux files. After post processing, direct covariance, inertial-dissipation and bulk turbulent flux will be produced at 10 min and hourly average. This will include mainly momentum, sensible and latent heat fluxes. All data for this project will be put on an ftp site back in Boulder.

```
For access to the FTP site:
ftp voodoo.etl.noaa.gov
username anonymous
password (email address)
cd et6/cruises/ WHOTS_2009
```

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Appendix A. Moored C-T Time Series Figures

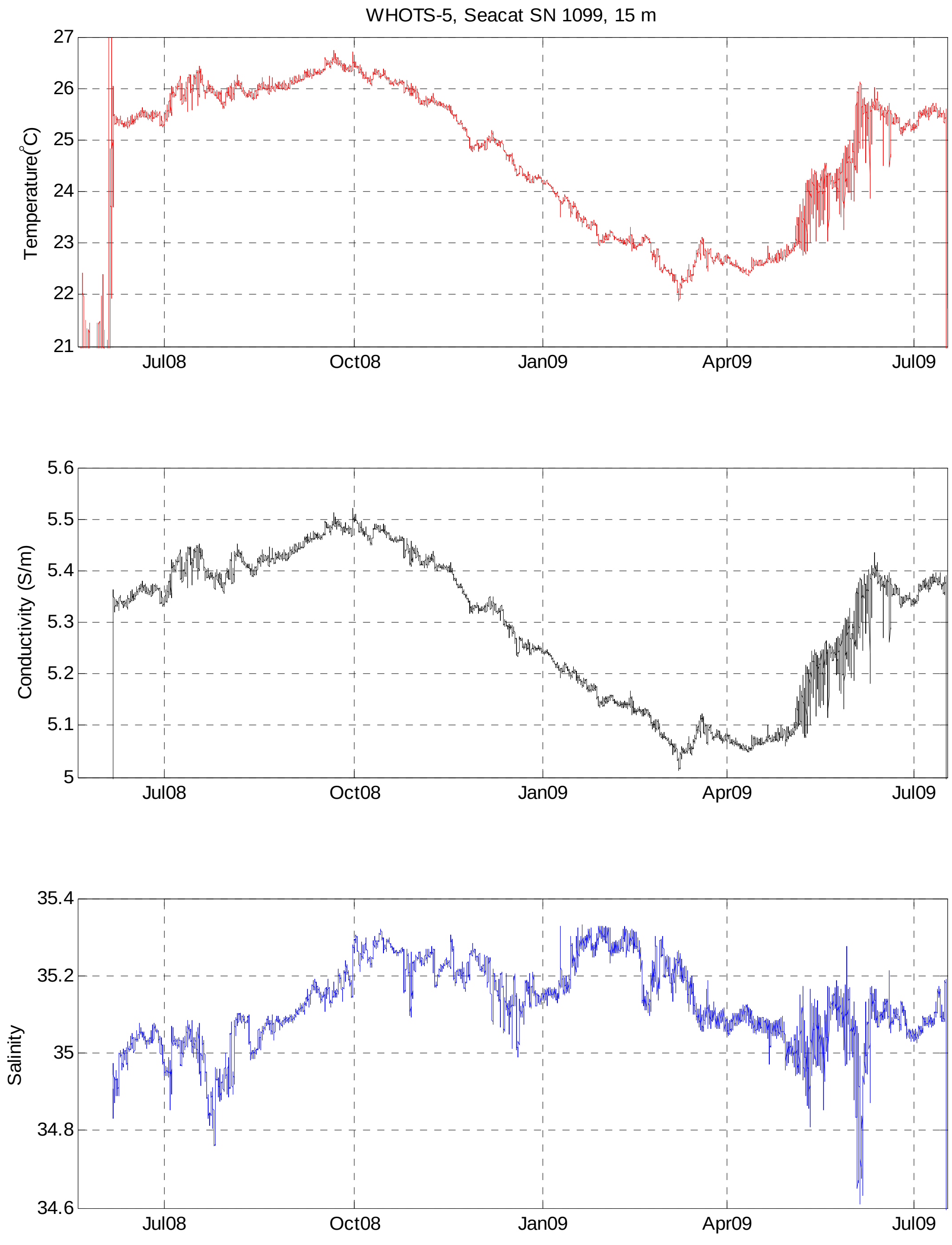

Figure A1. Preliminary temperature, conductivity and salinity from Seacat SBE-16 SN 1099 deployed at 15 m on the WHOTS-5 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

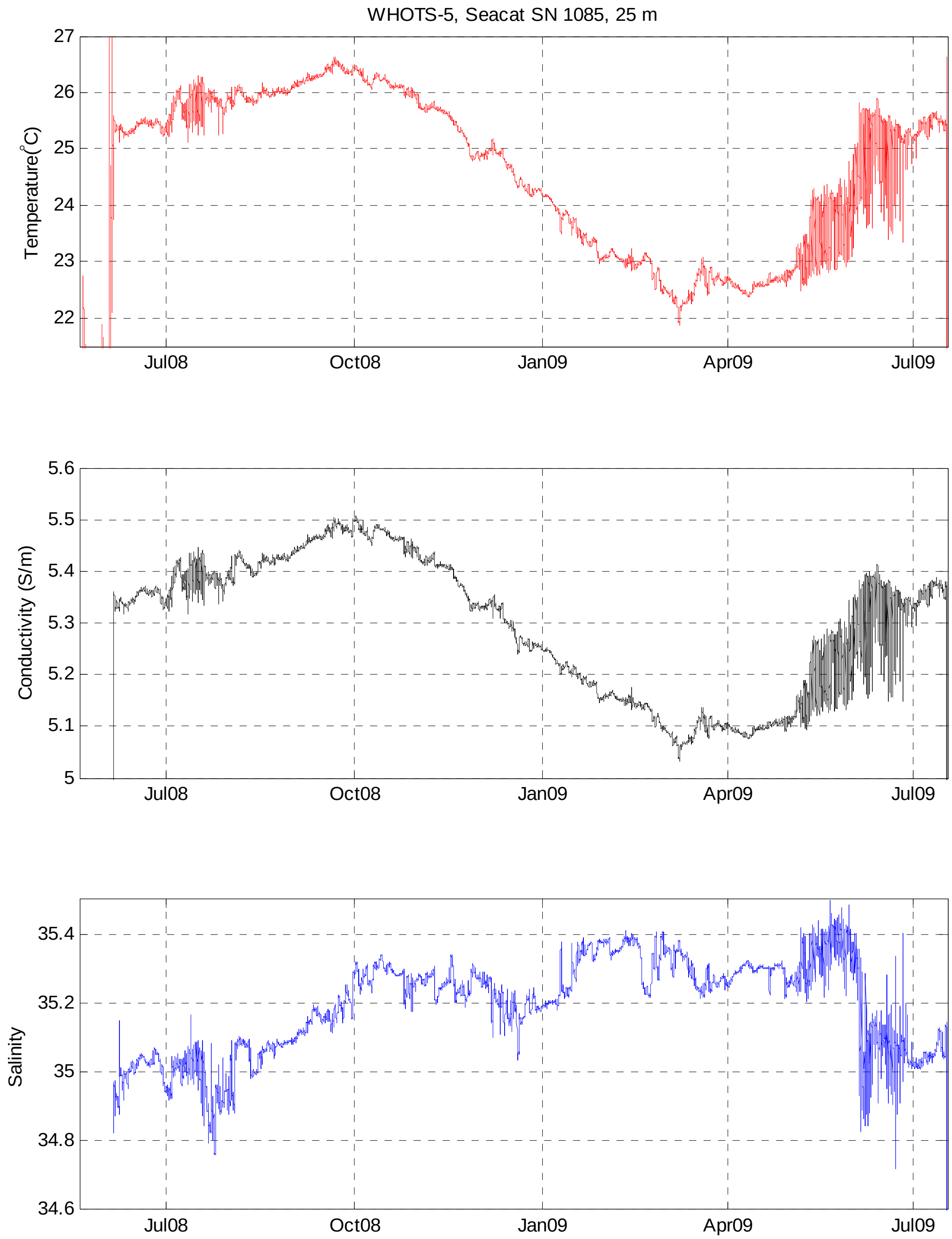

Figure A2. Preliminary temperature, conductivity and salinity from Seacat SBE-16 SN 1085 deployed at 25 m on the WHOTS-5 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

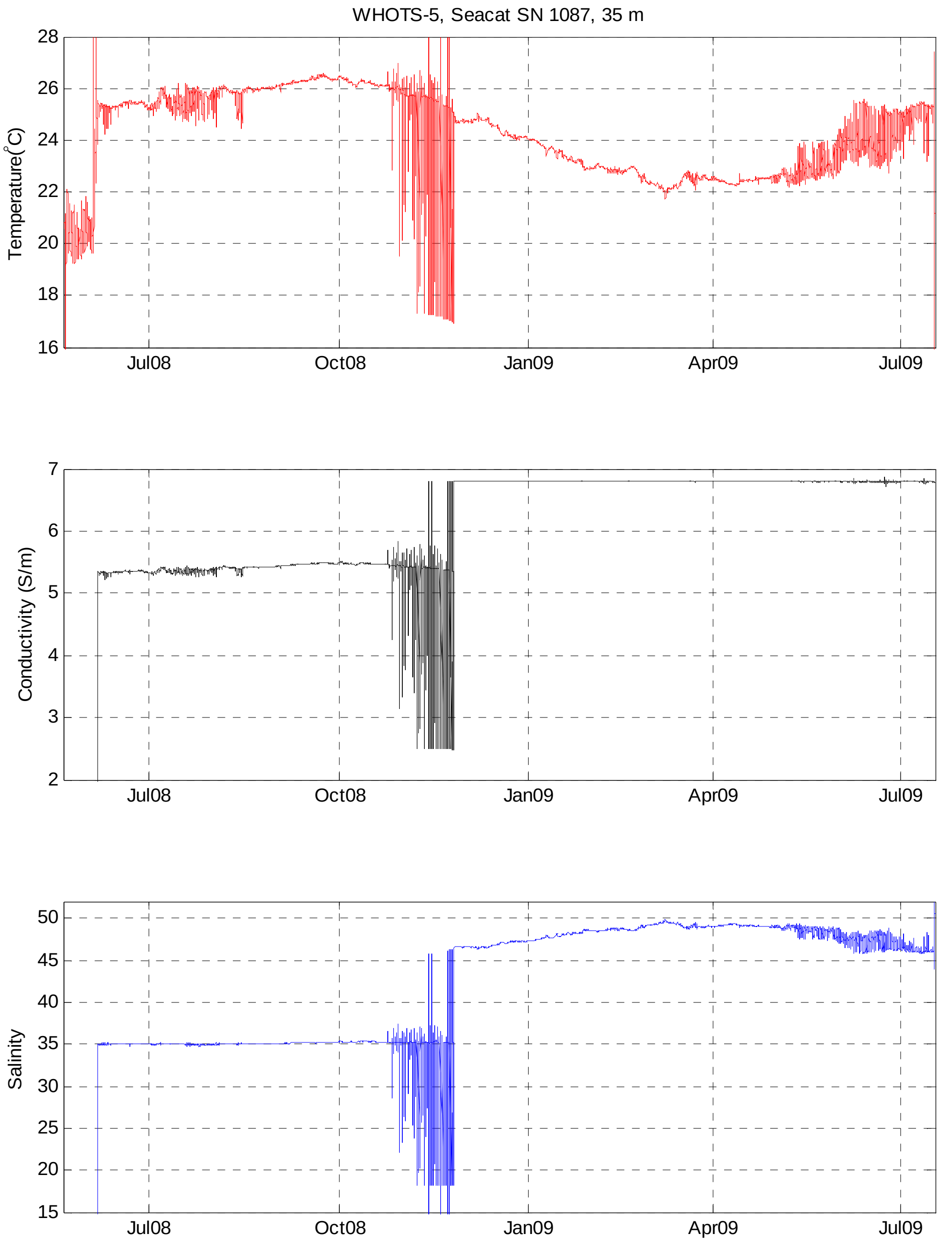

Figure A3. Preliminary temperature, conductivity and salinity from Seacat SBE-16 SN 1087 deployed at 35 m on the WHOTS-5 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available. The sensors recorded noisy data during November, followed by an offset in the conductivity.

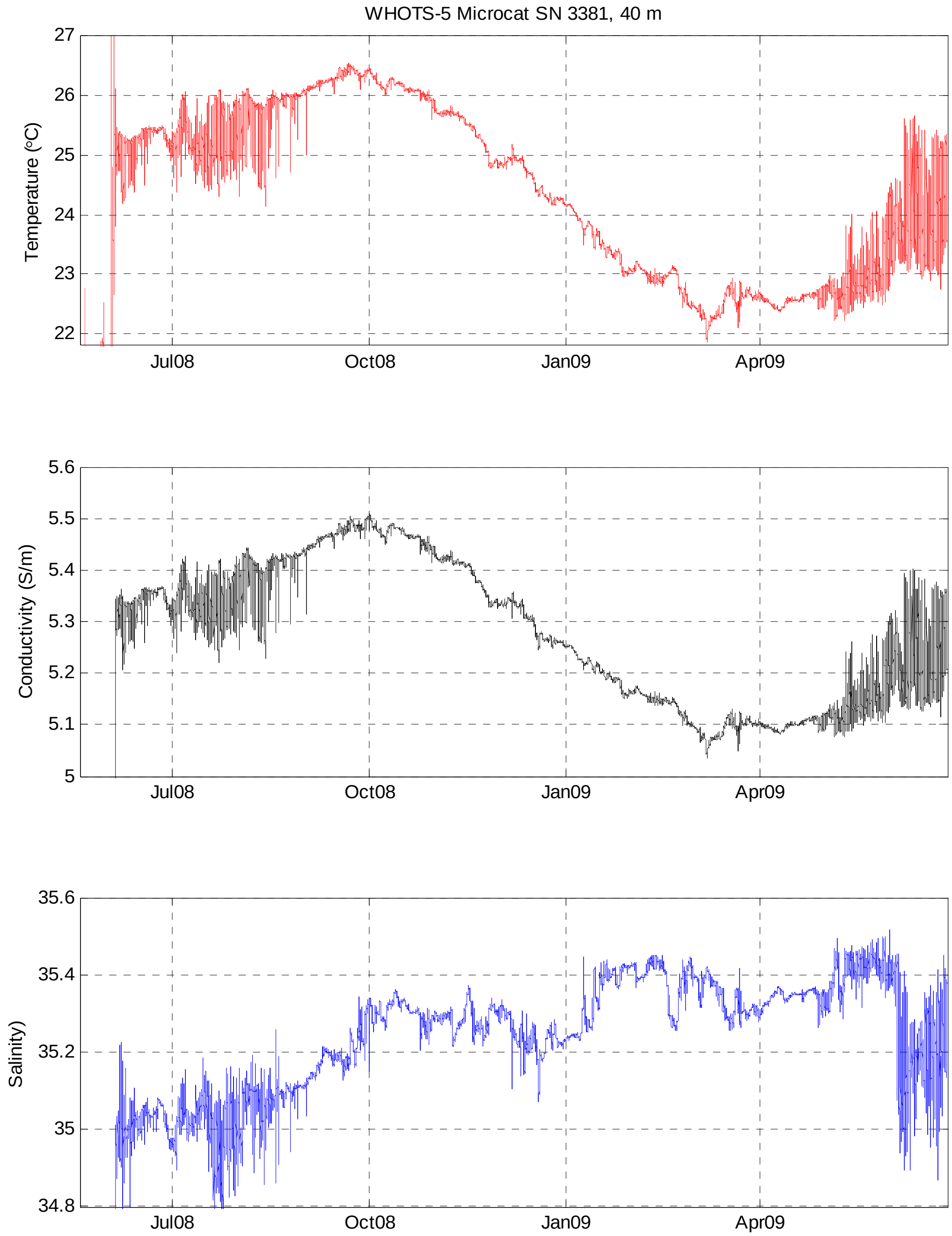

Figure A4. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 3381 deployed at 40 m on the WHOTS-5 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

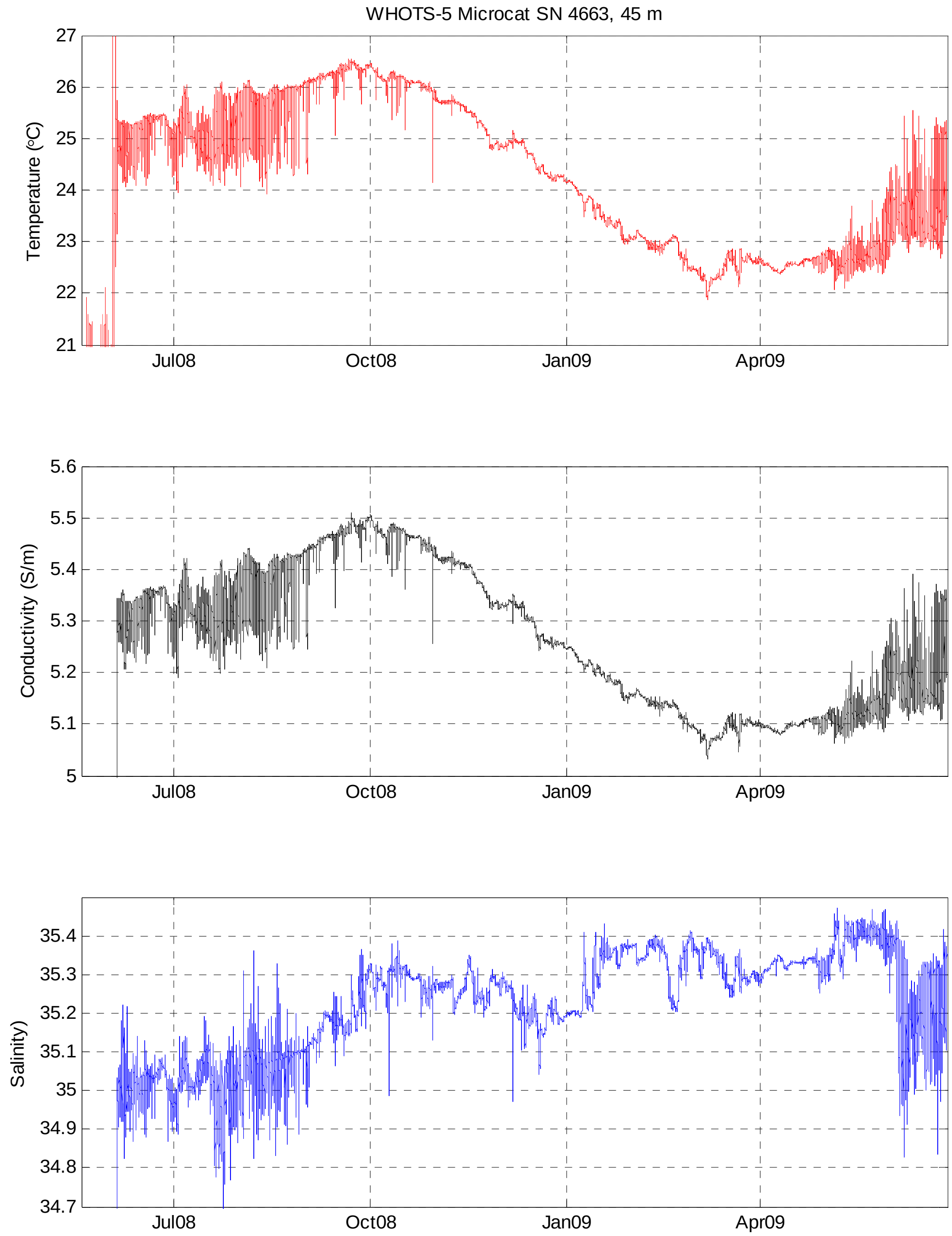

Figure A5. Preliminary temperature, conductivity and salinity from Microcat SBE-37 SN 4663 deployed at 45 m on the WHOTS-5 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

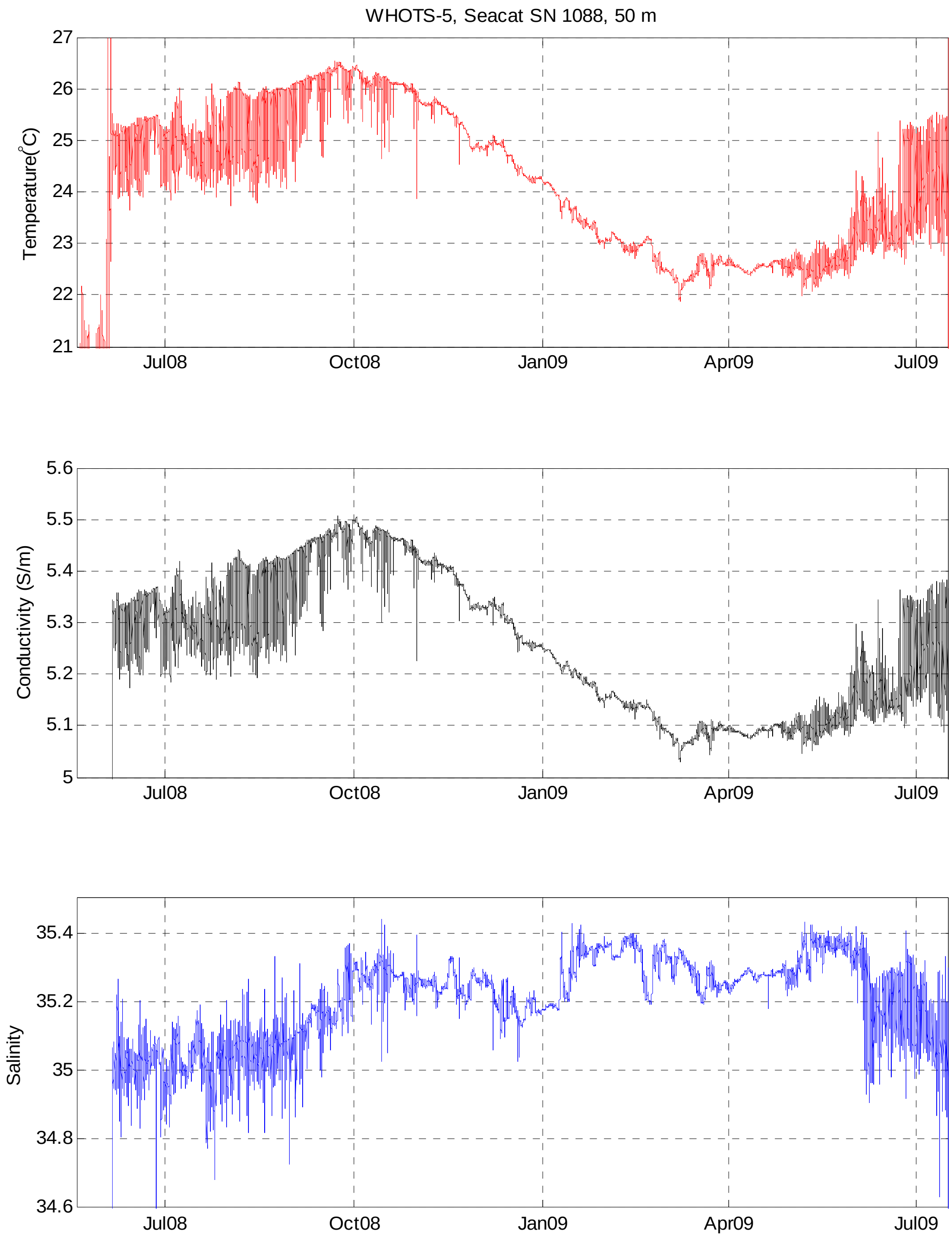

Figure A6. Preliminary temperature, conductivity and salinity from Seacat SBE-16 SN 1088 deployed at 50 m on the WHOTS-5 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

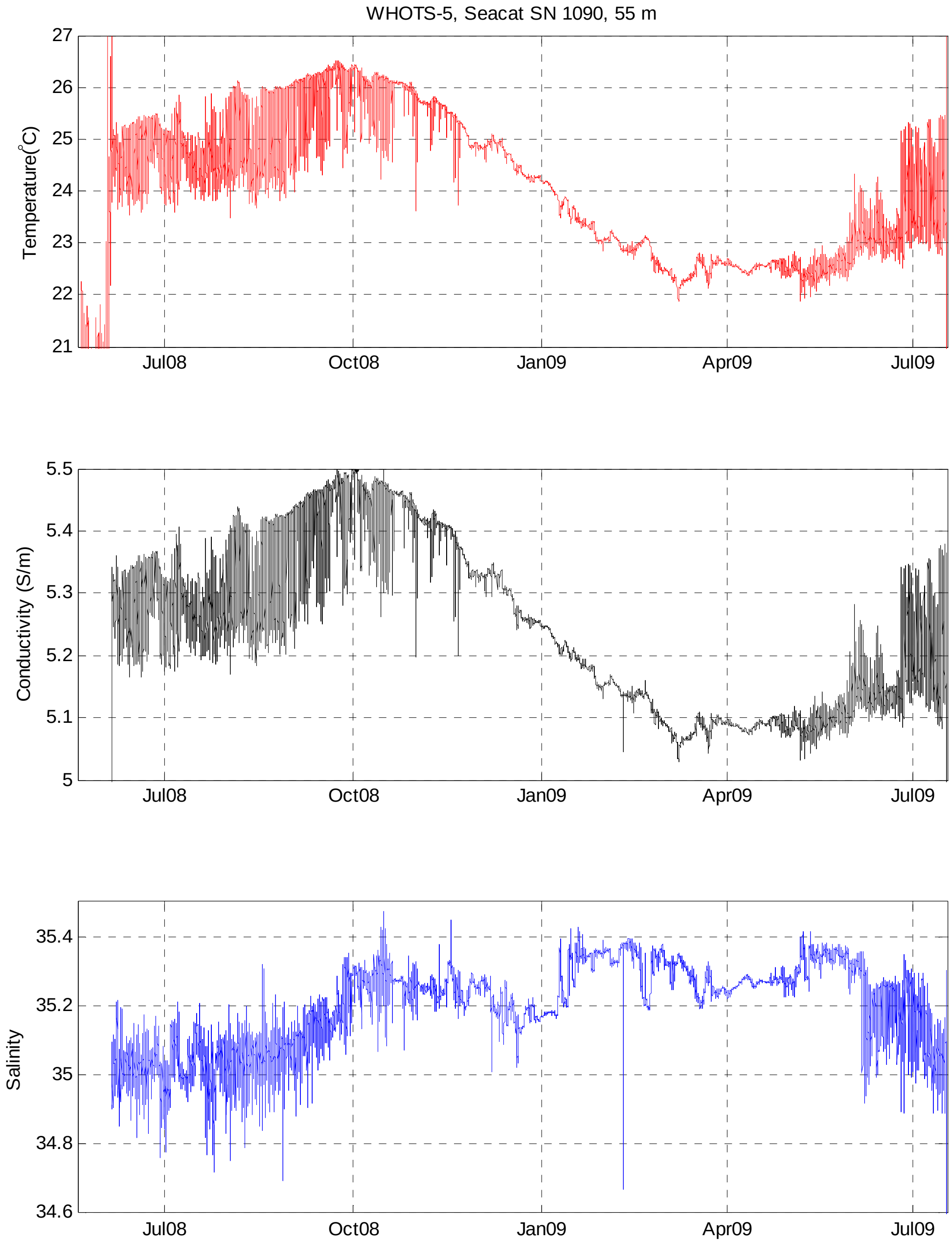

Figure A7. Preliminary temperature, conductivity and salinity from Seacat SBE-16 SN 1090 deployed at 55 m on the WHOTS-5 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

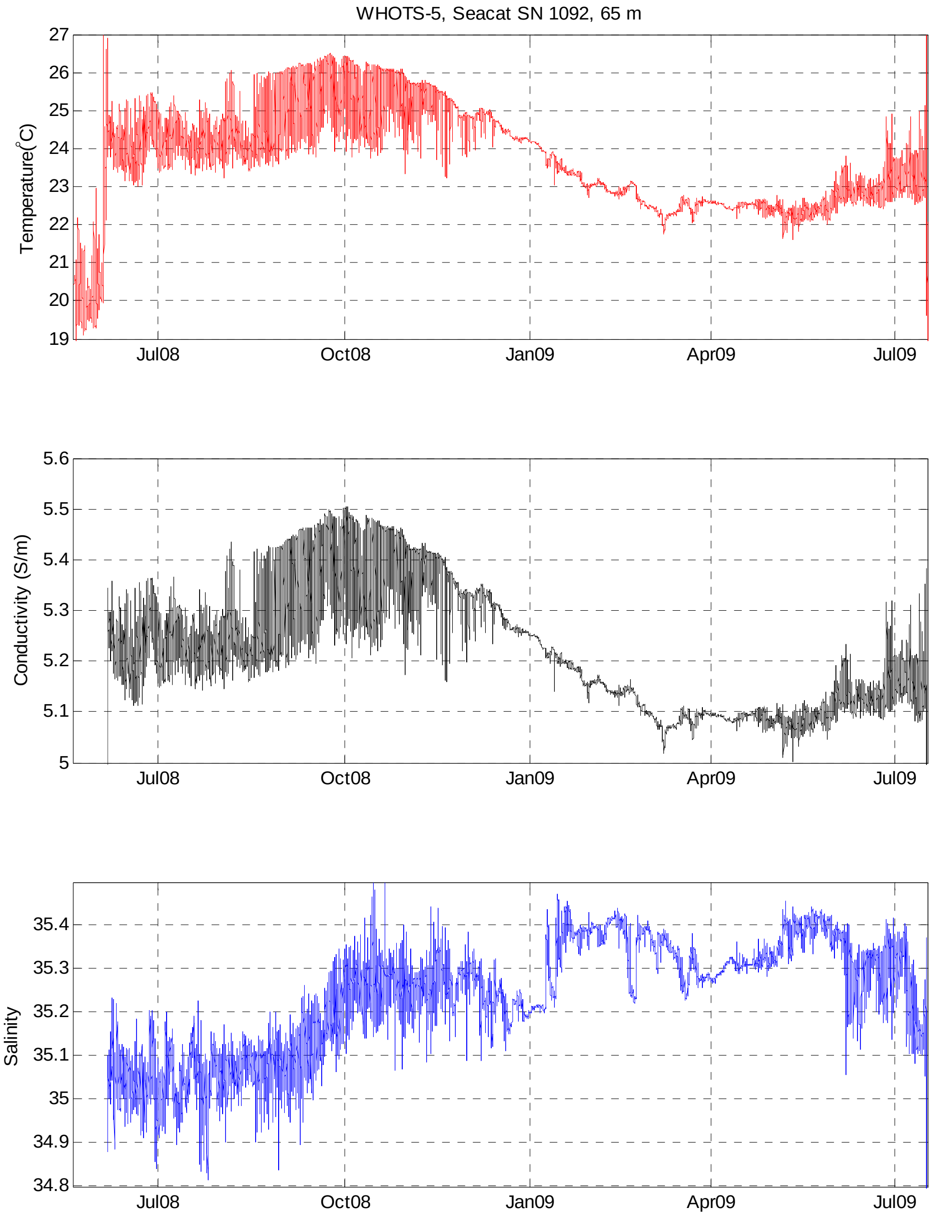

Figure A8. Preliminary temperature, conductivity and salinity from Seacat SBE-16 SN 1092 deployed at 65 m on the WHOTS-5 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

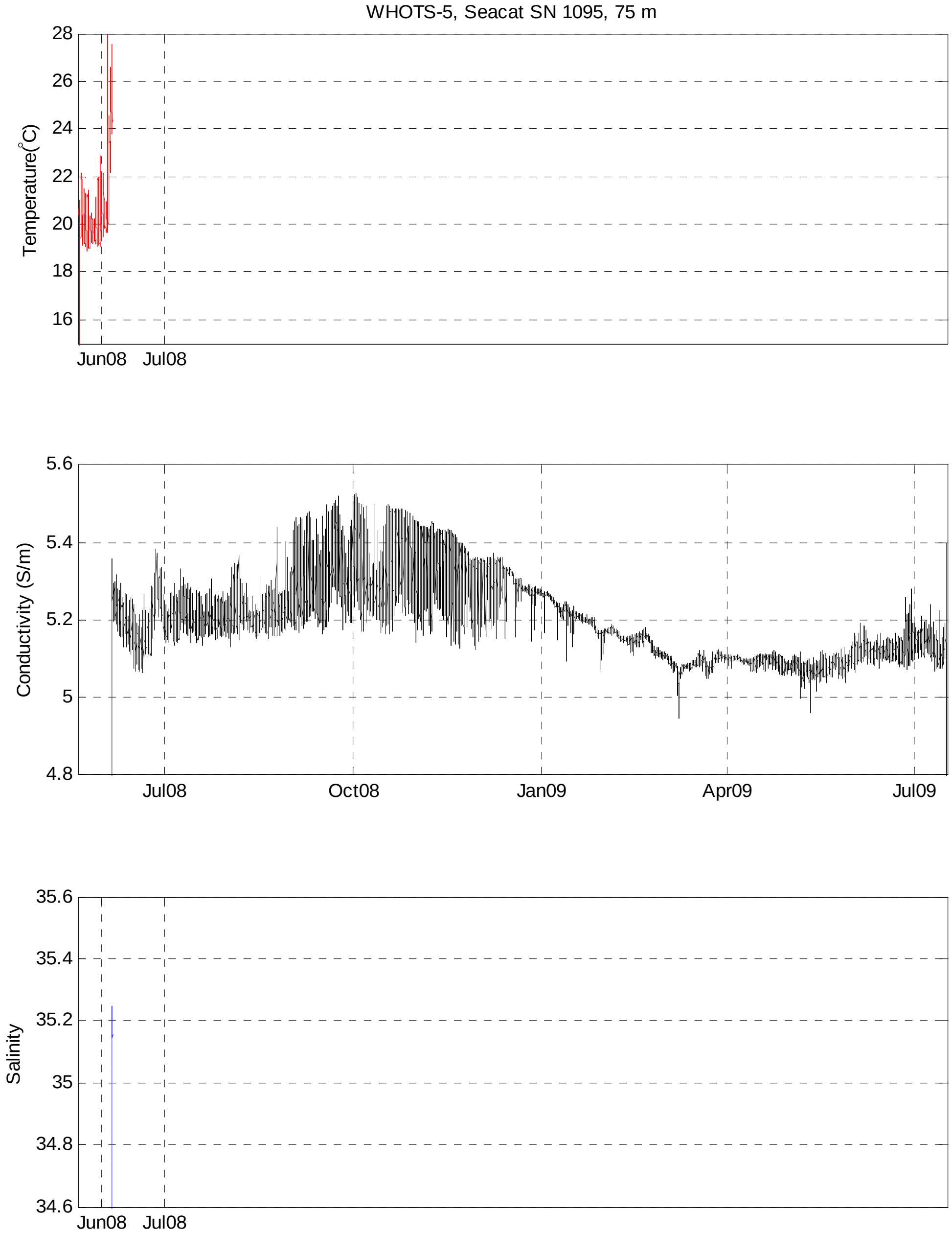

Figure A9. Preliminary temperature, conductivity and salinity from Seacat SBE-16 SN 1095 deployed at 75 m on the WHOTS-5 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available. The temperature sensor failed soon after deployment.

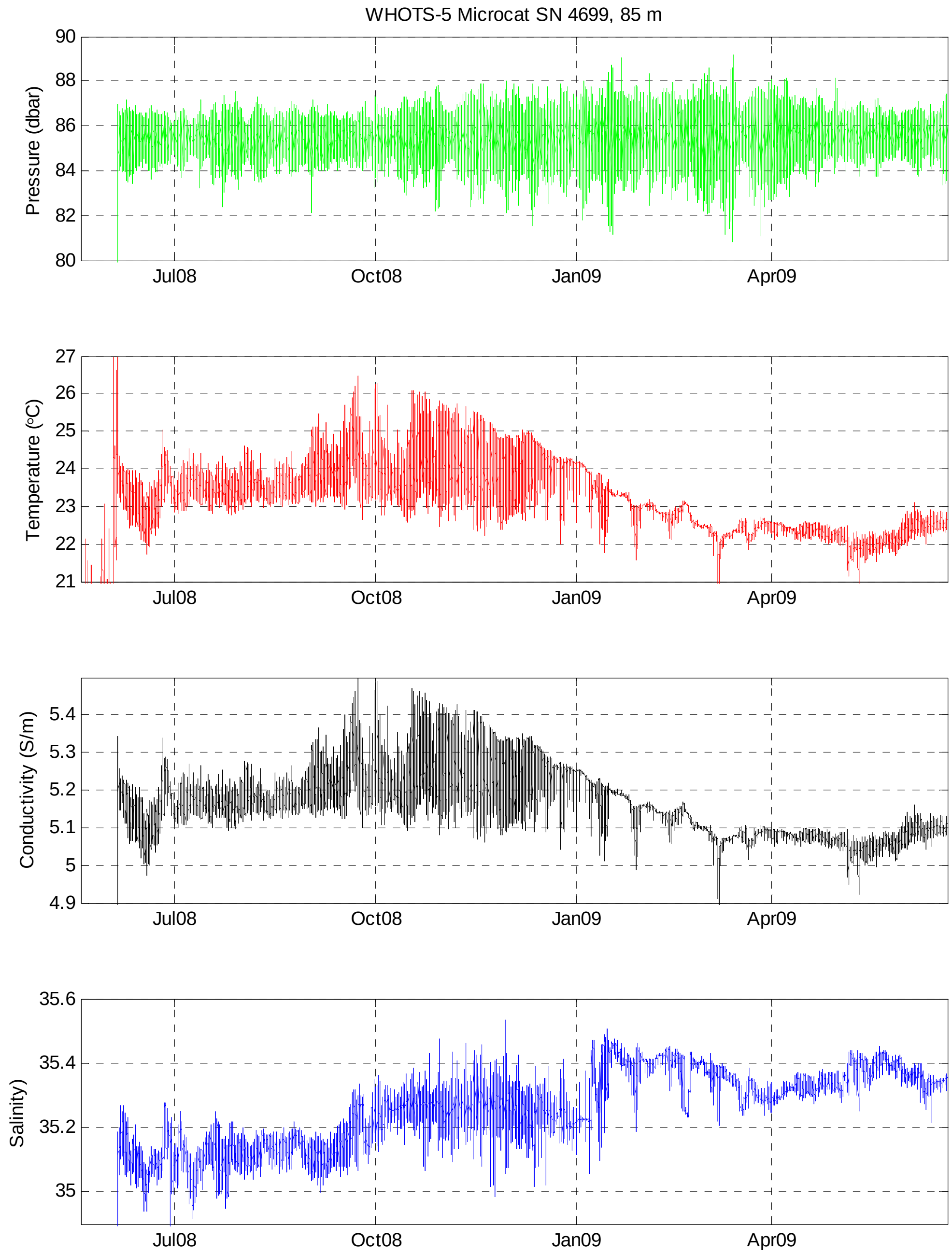

Figure A10. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 4699 deployed at 85 m on the WHOTS-5 mooring.

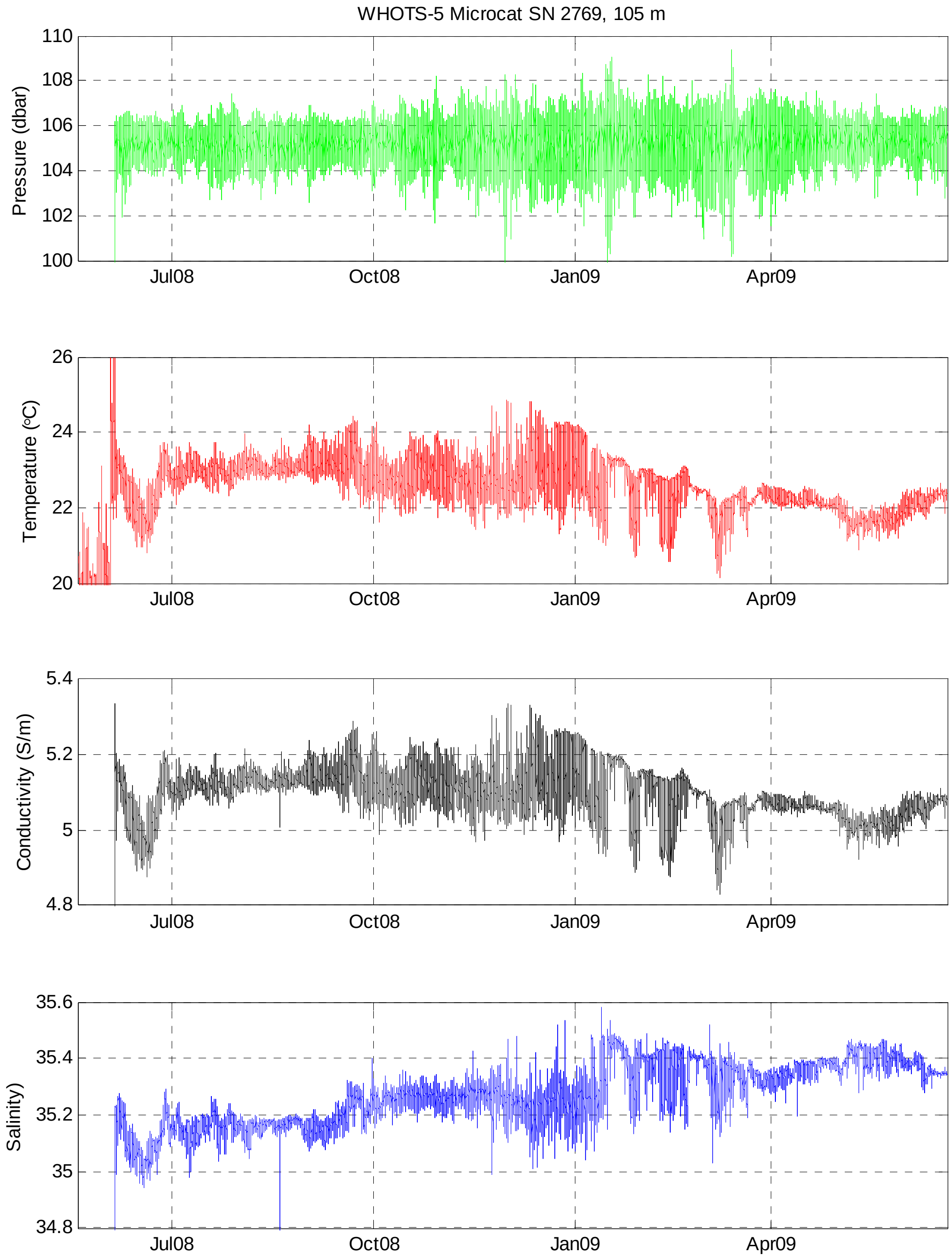

Figure A11. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 2769 deployed at 105 m on the WHOTS-5 mooring.

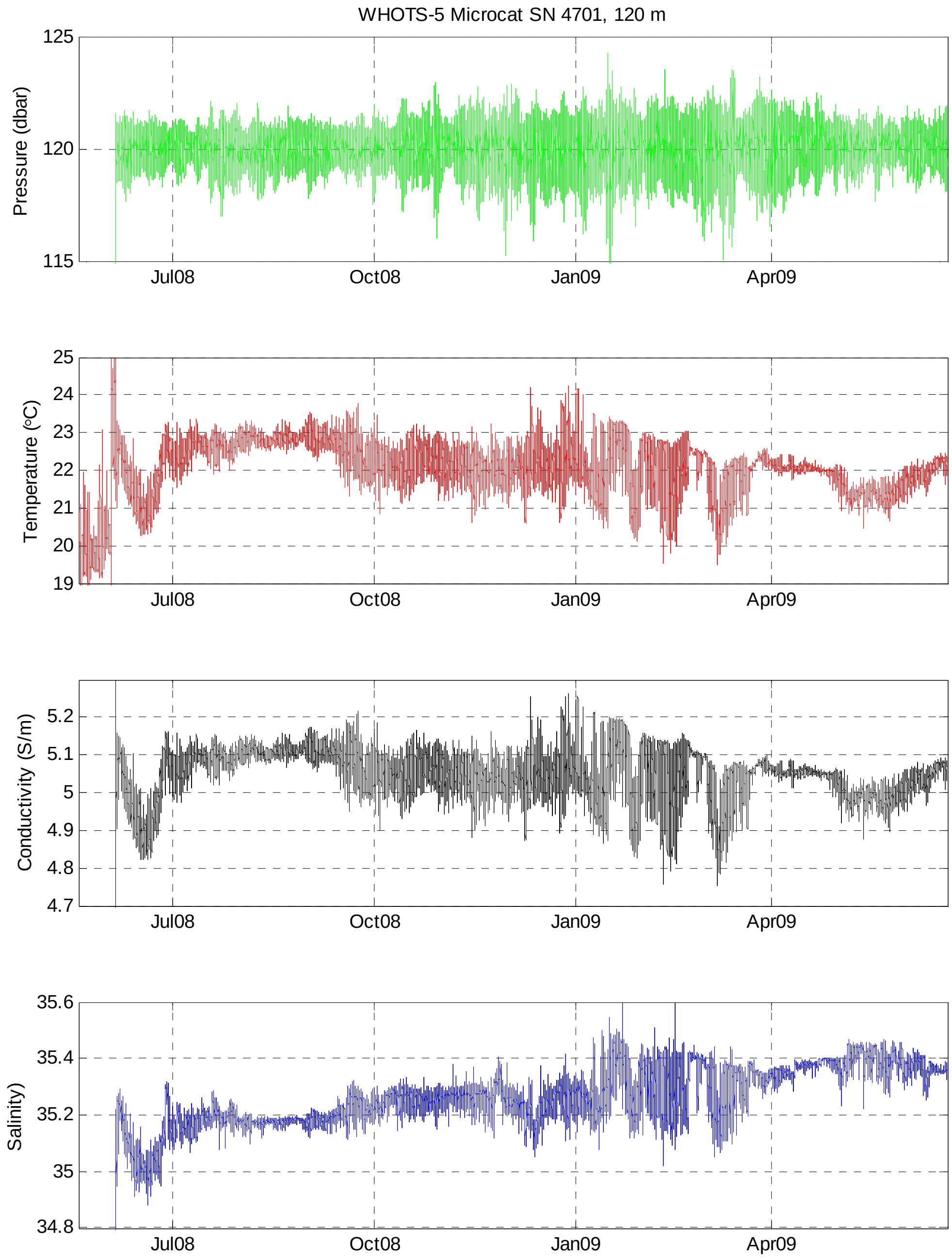

Figure A12. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 4701 deployed at 120 m on the WHOTS-5 mooring.

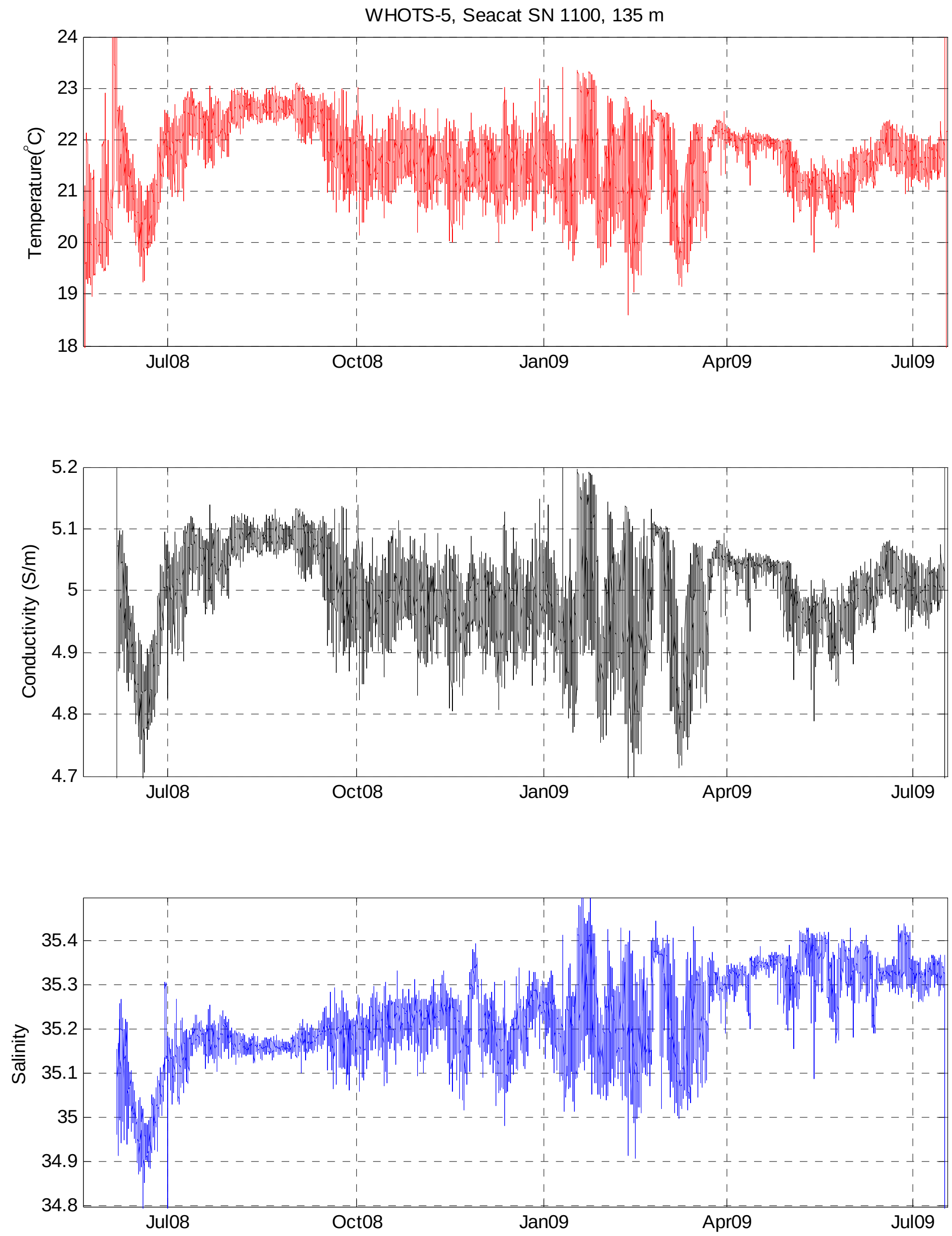

Figure A13. Preliminary temperature, conductivity and salinity from Seacat SBE-16 SN 1100 deployed at 135 m on the WHOTS-5 mooring. Nominal pressure is also included to calculate salinity where pressure data was not available.

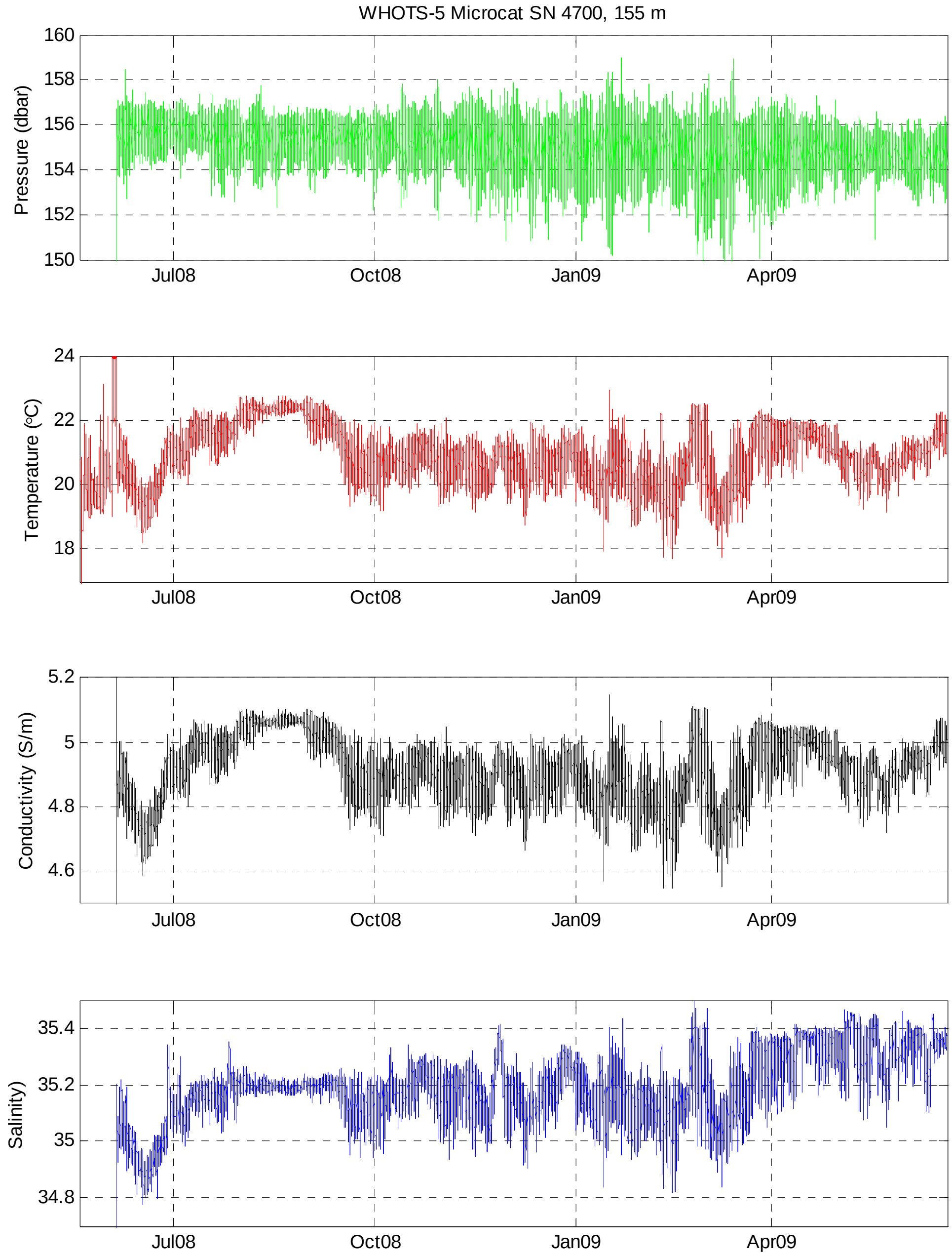

Figure A14. Preliminary pressure, temperature, conductivity and salinity from Microcat SBE-37 SN 4700 deployed at 155 m on the WHOTS-5 mooring.

Appendix B. CTD Casts Figures

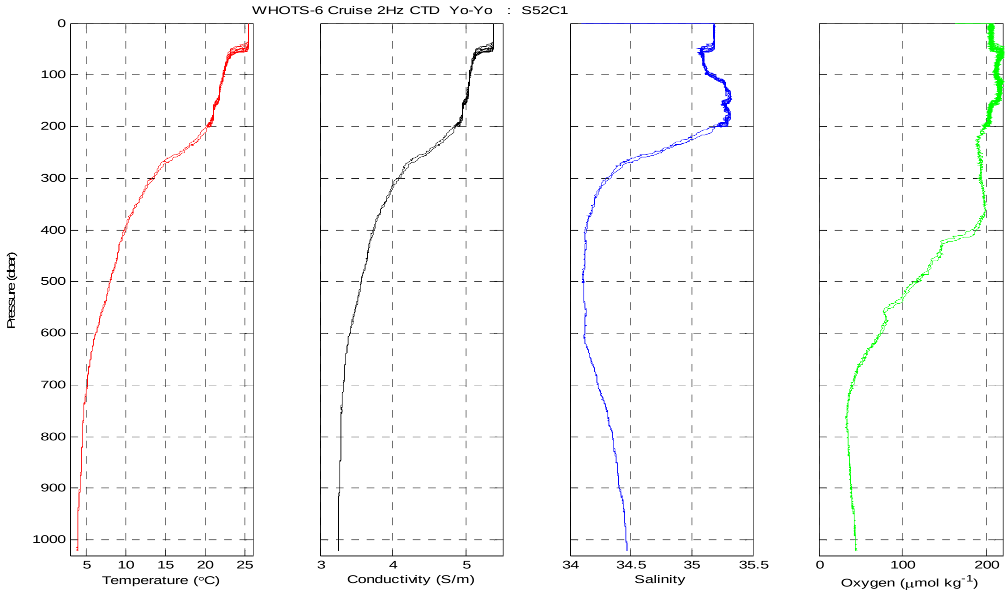

Figure B1. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S52C1.

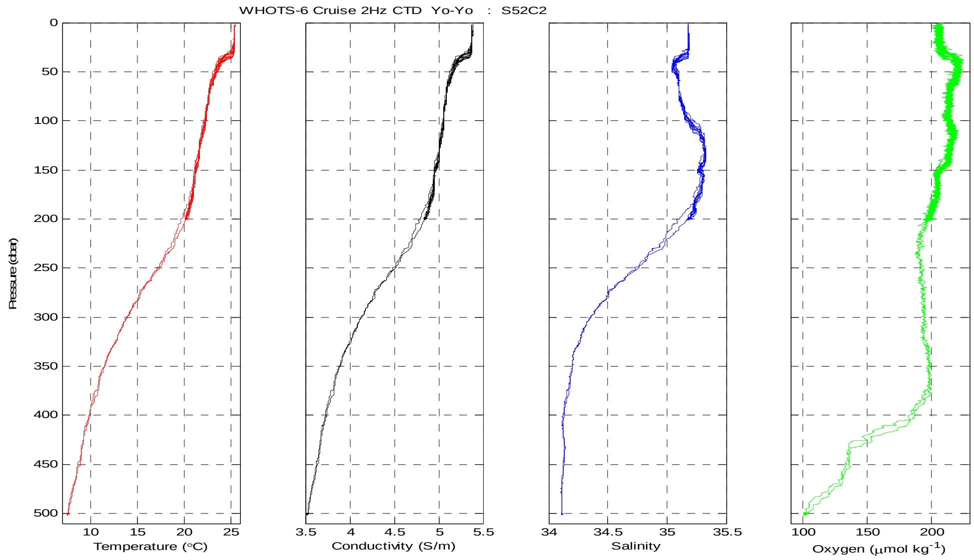

Figure B2. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S52C2.

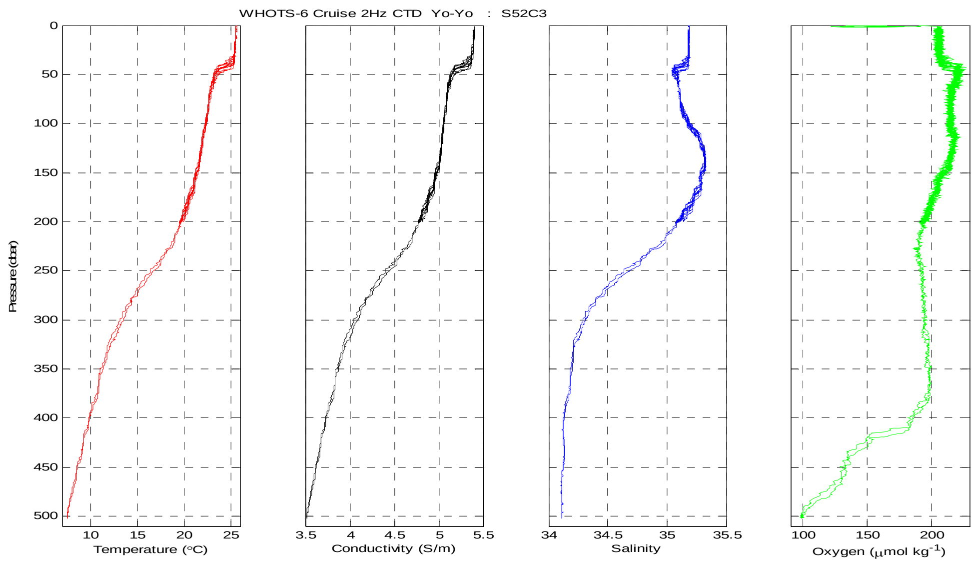

Figure B3. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S52C3

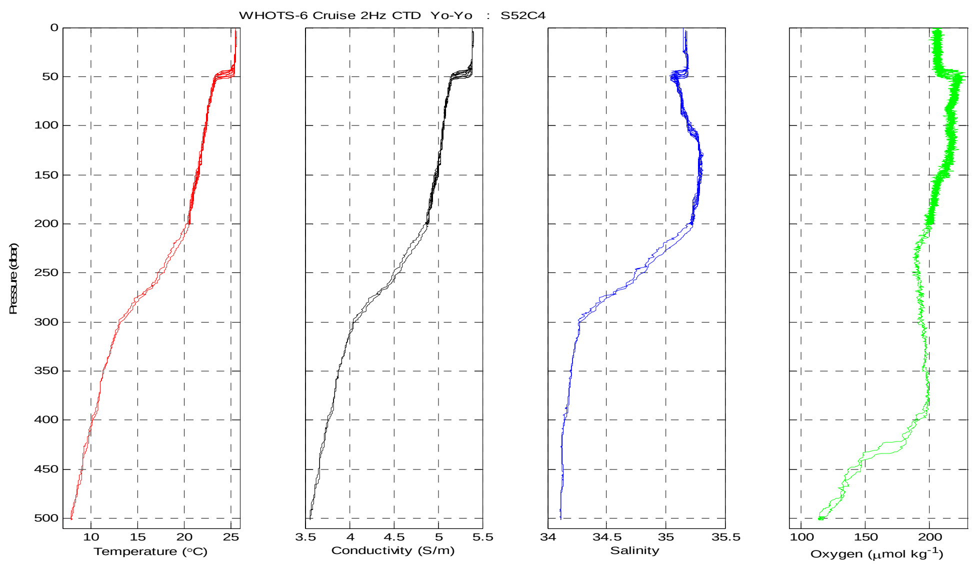

Figure B4. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S52C4.

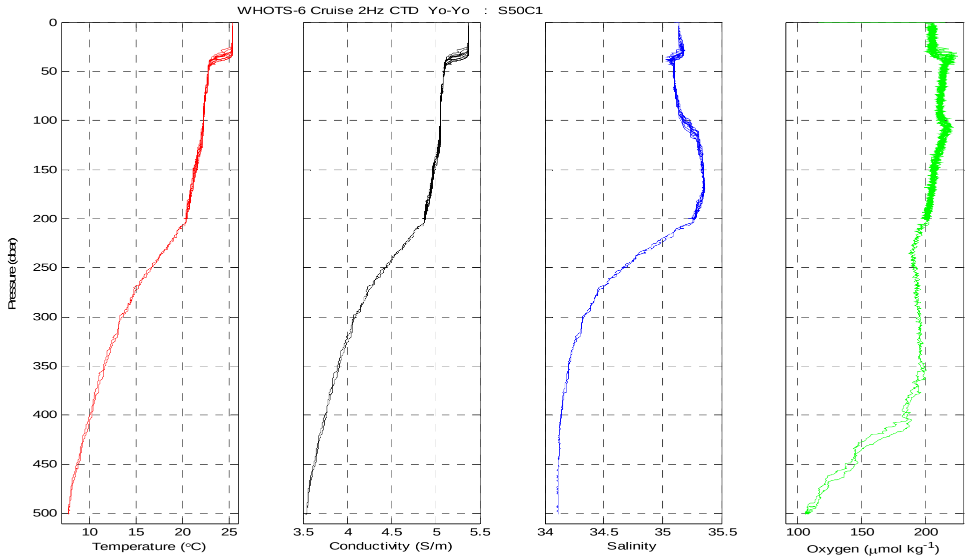

Figure B5. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S50C1.

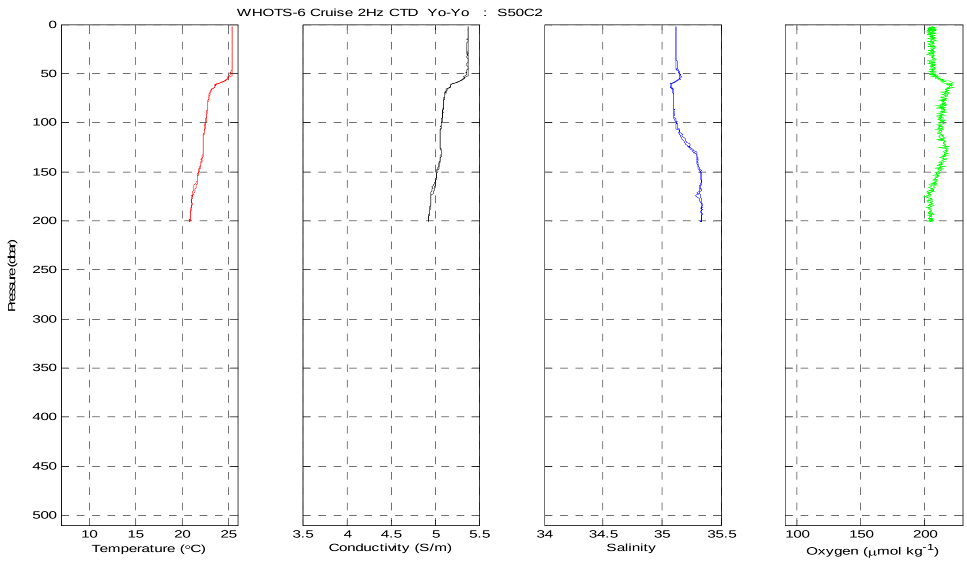

Figure B6. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S50C2.

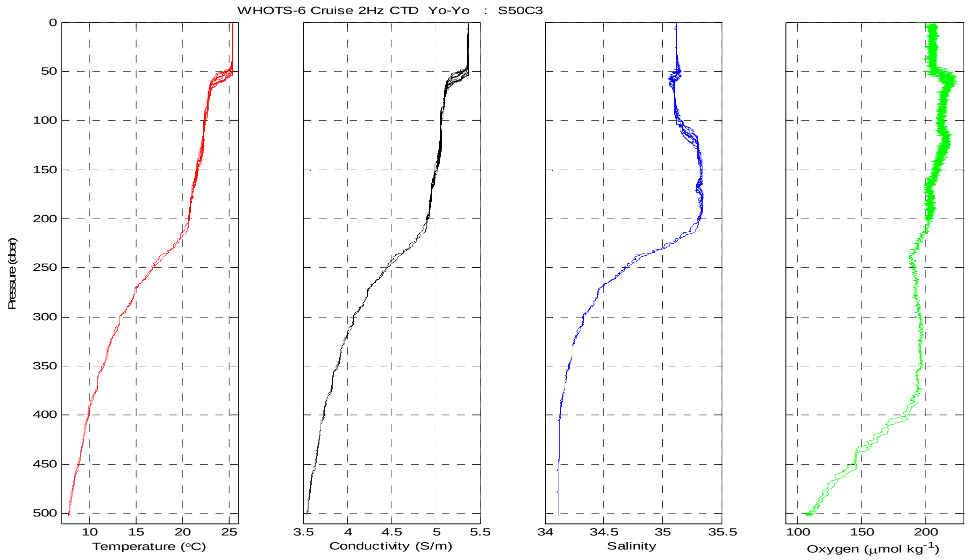

Figure B7. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S50C3.

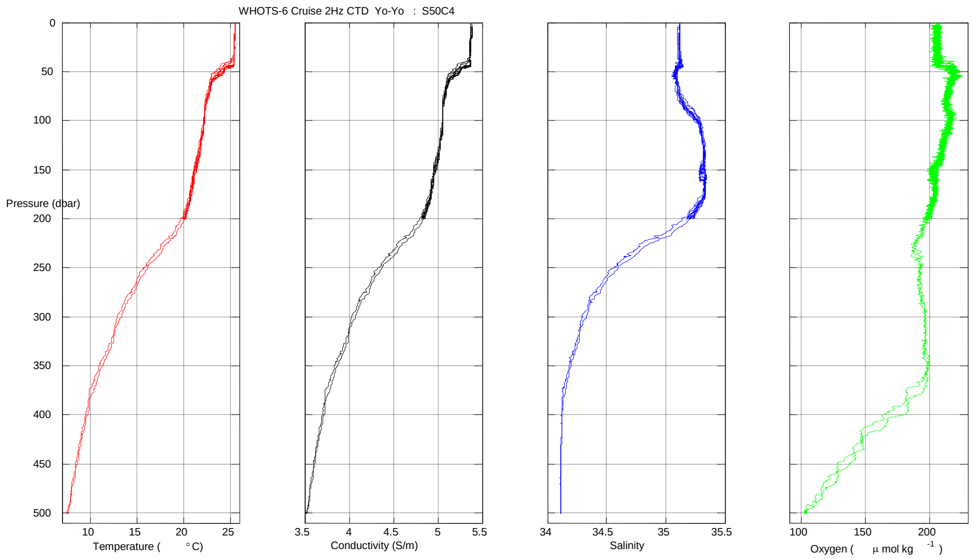

Figure B8. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S50C4

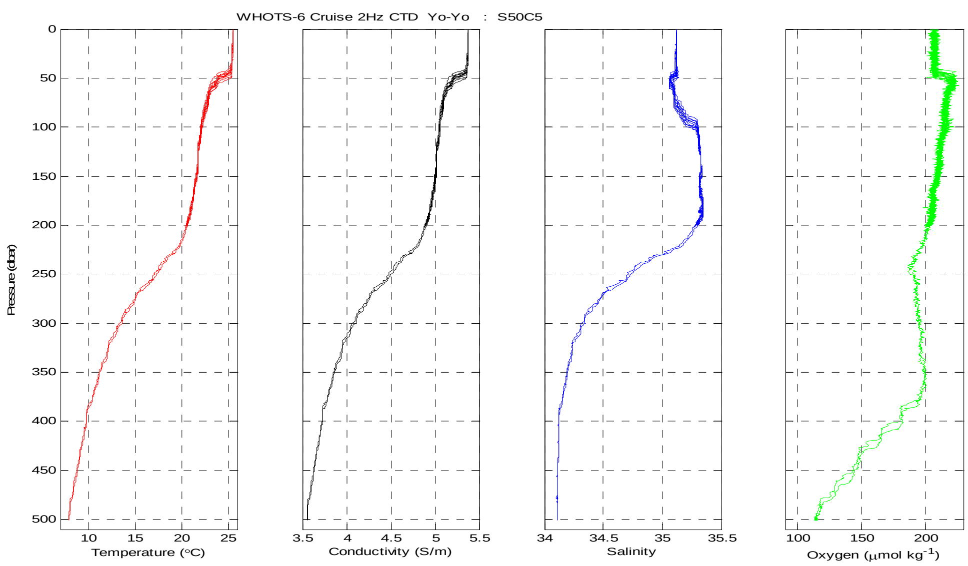

Figure B9. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S50C5.

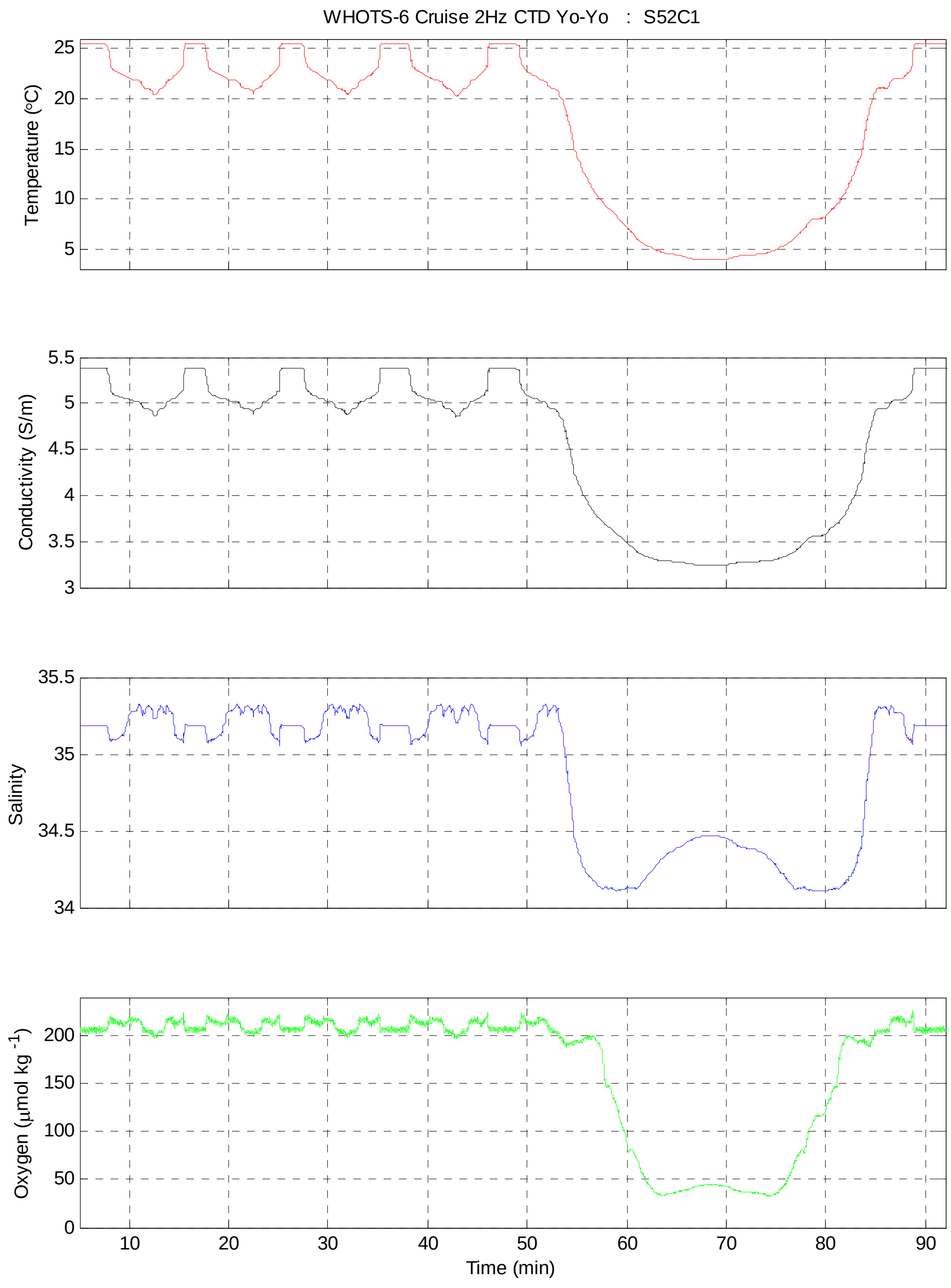

Figure B10. Profiles of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S52C1.

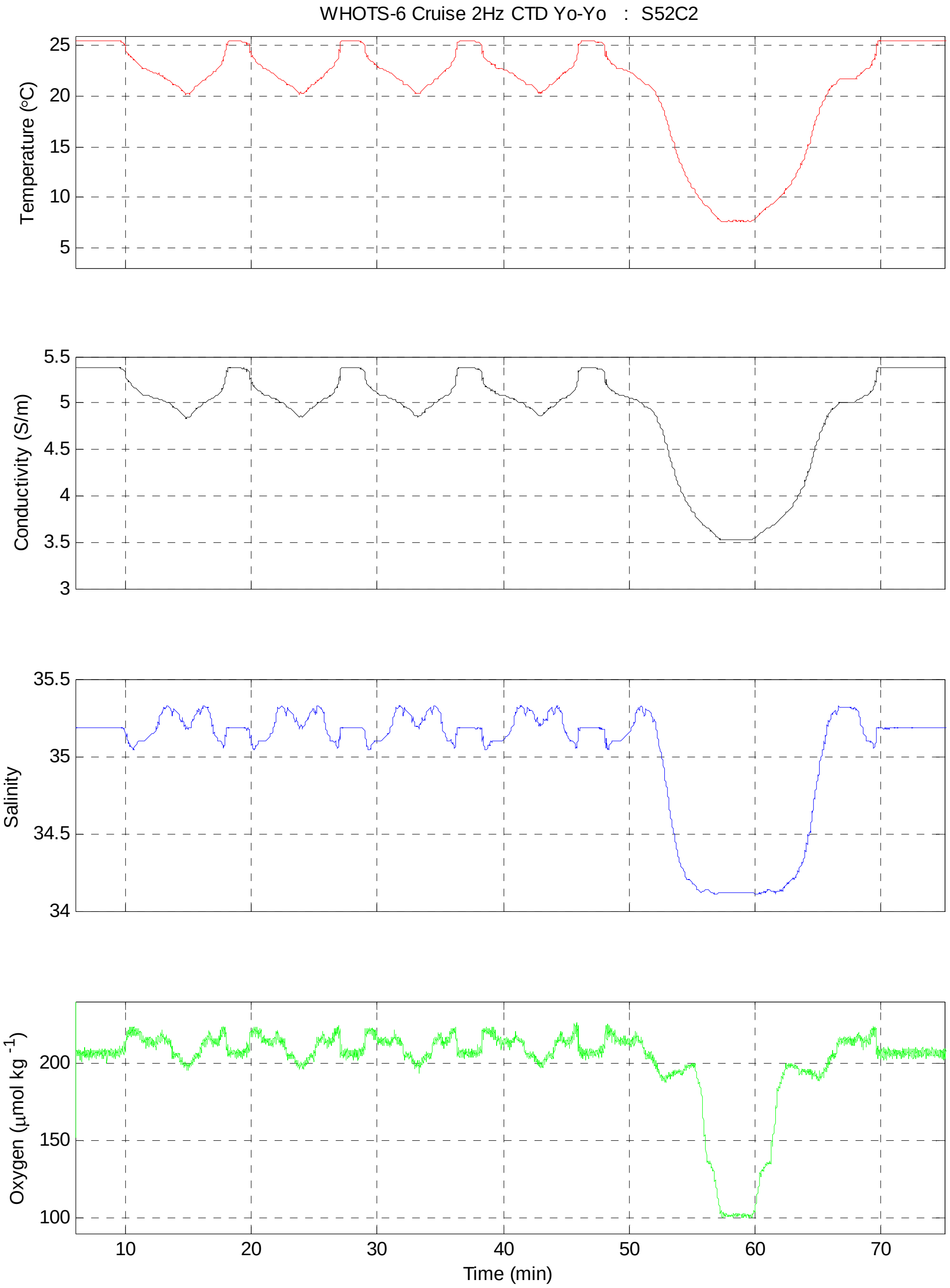

Figure B11. Time-series of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S52C2.

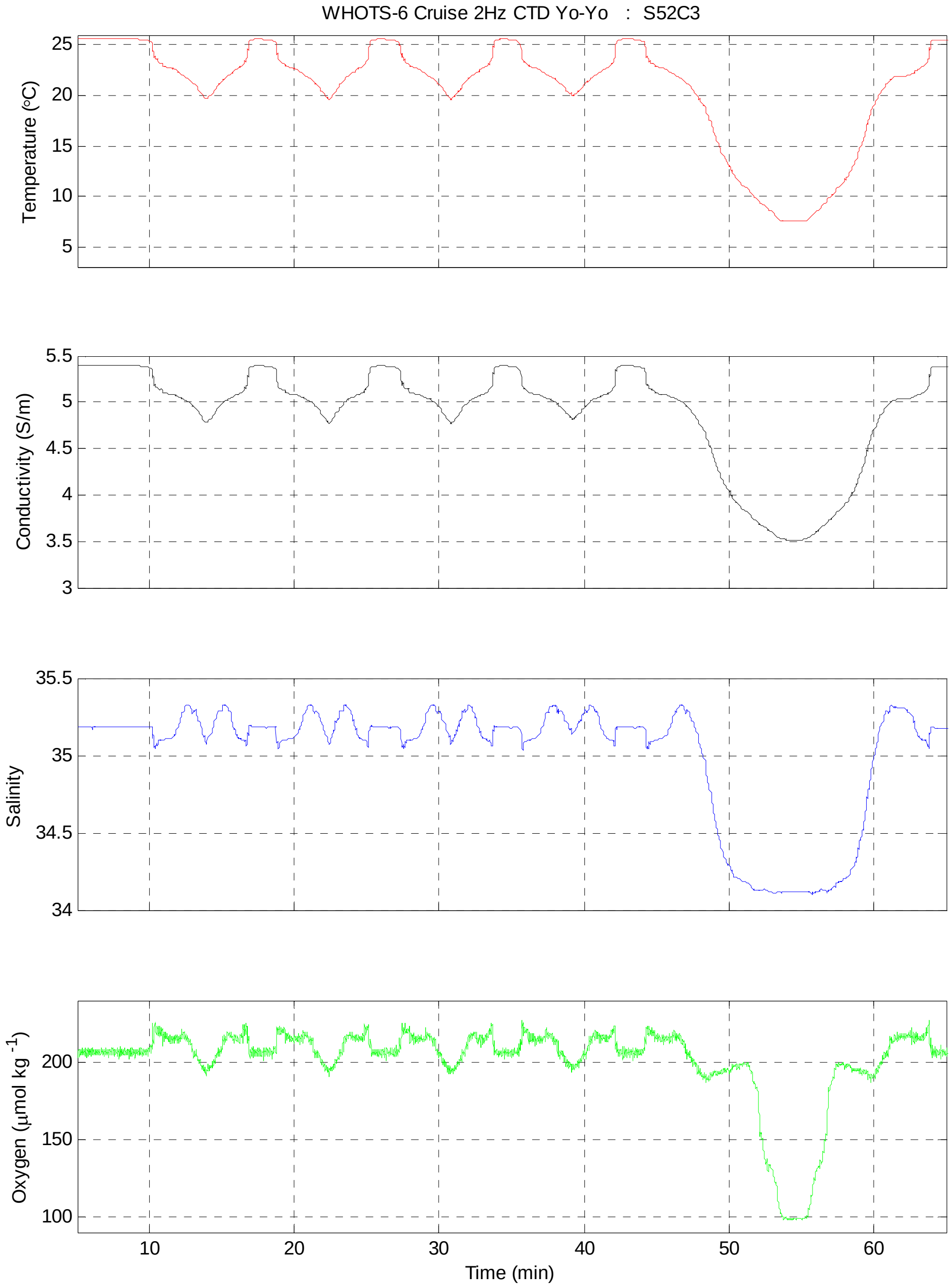

Figure B12. Time-series of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S52C3.

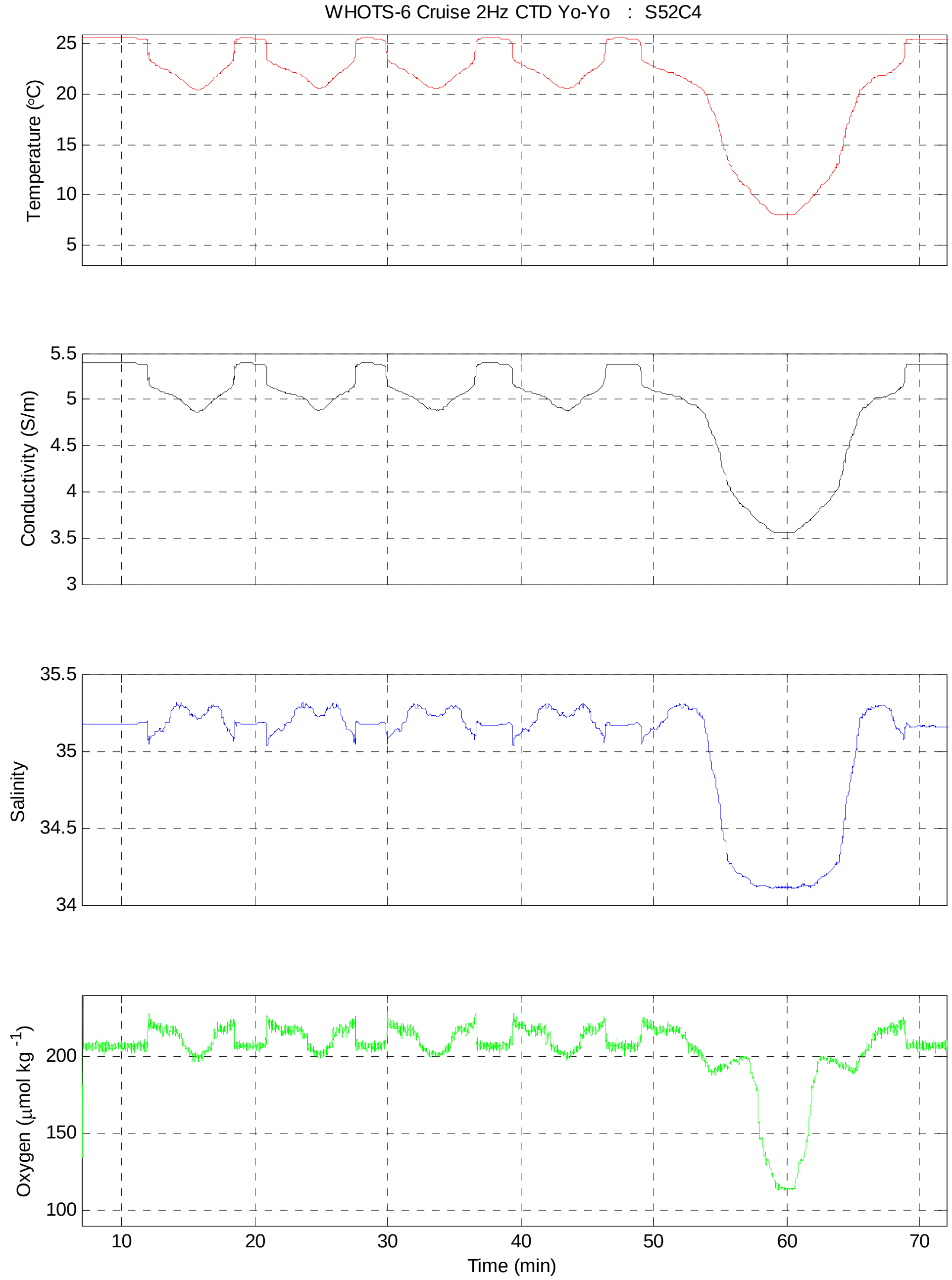

Figure B13. Time-series of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S52C4.

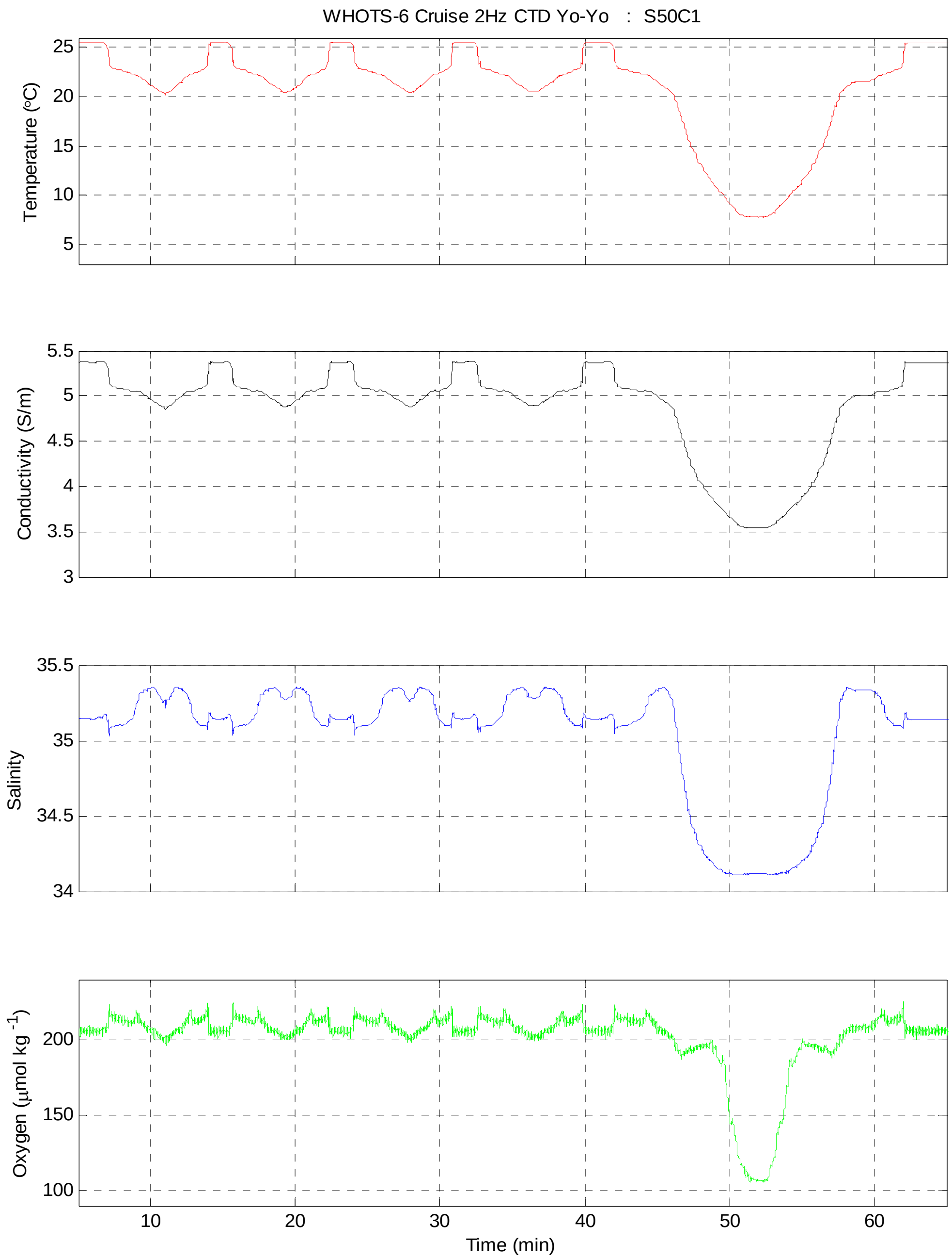

Figure B14. Time-series of 2 Hz temperature, conductivity, salinity and oxygen data during CTD S50C1.

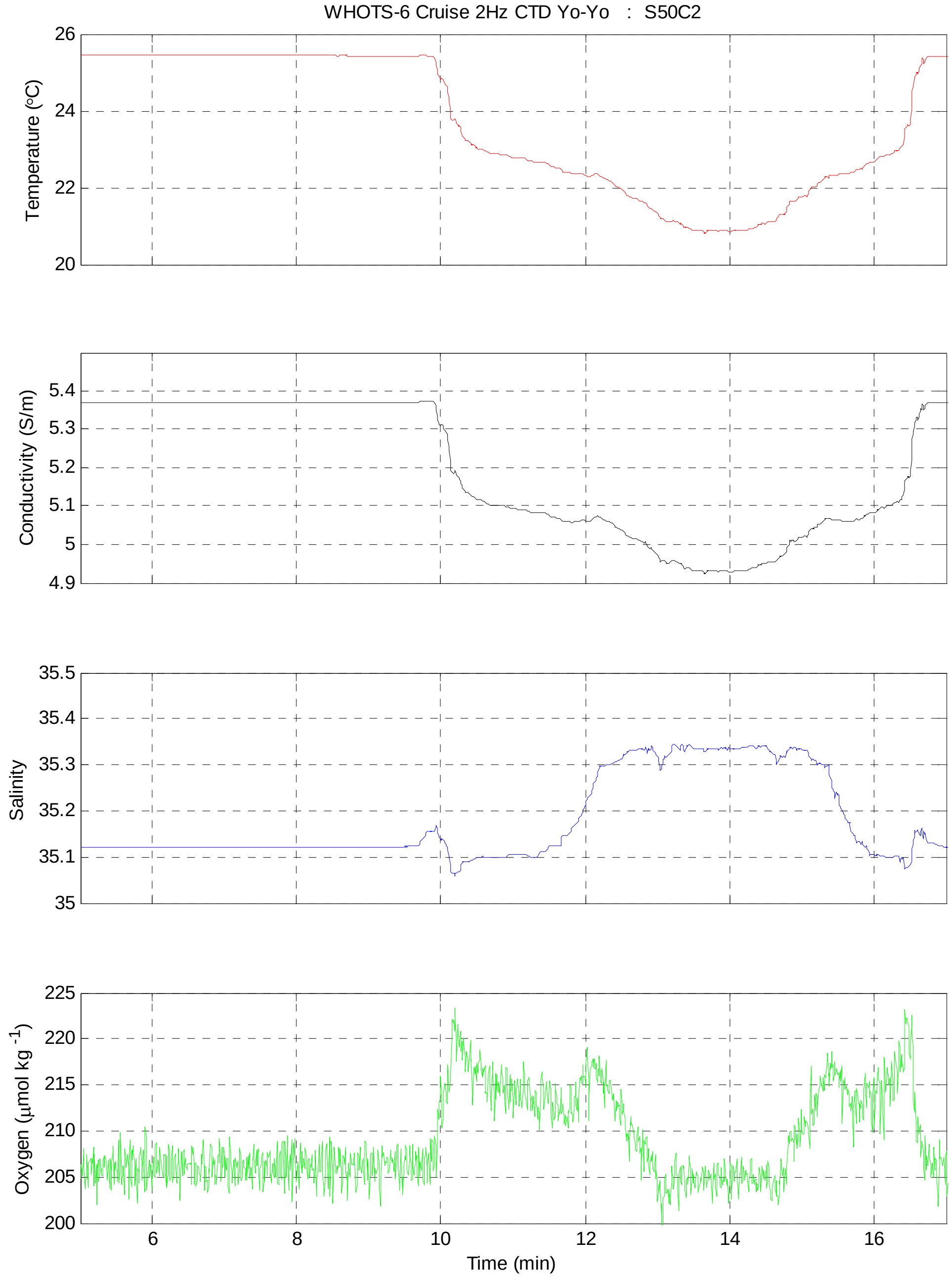

Figure B15. Time-series of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S50C2.

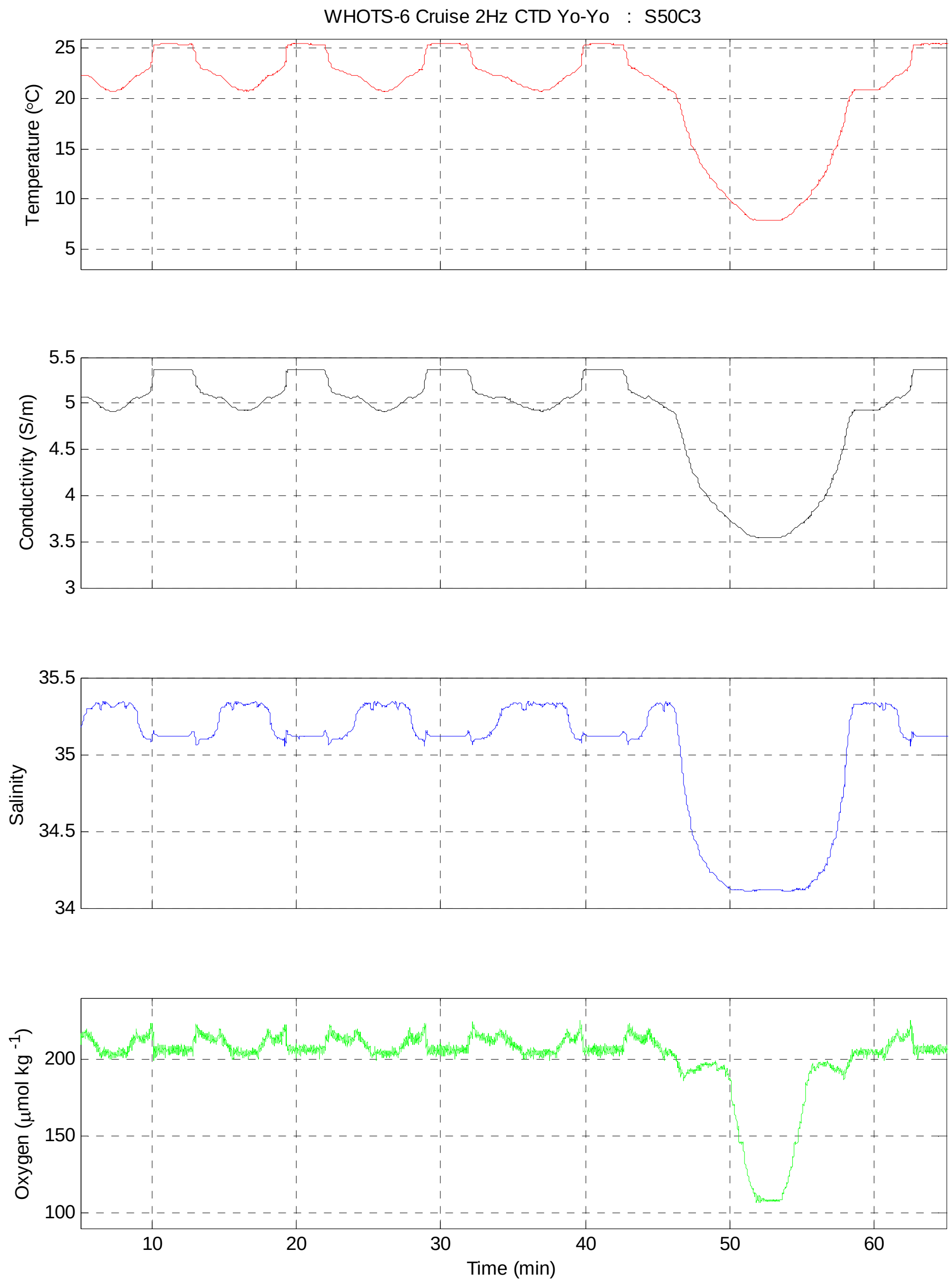

Figure B16. Time-series of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S50C3.

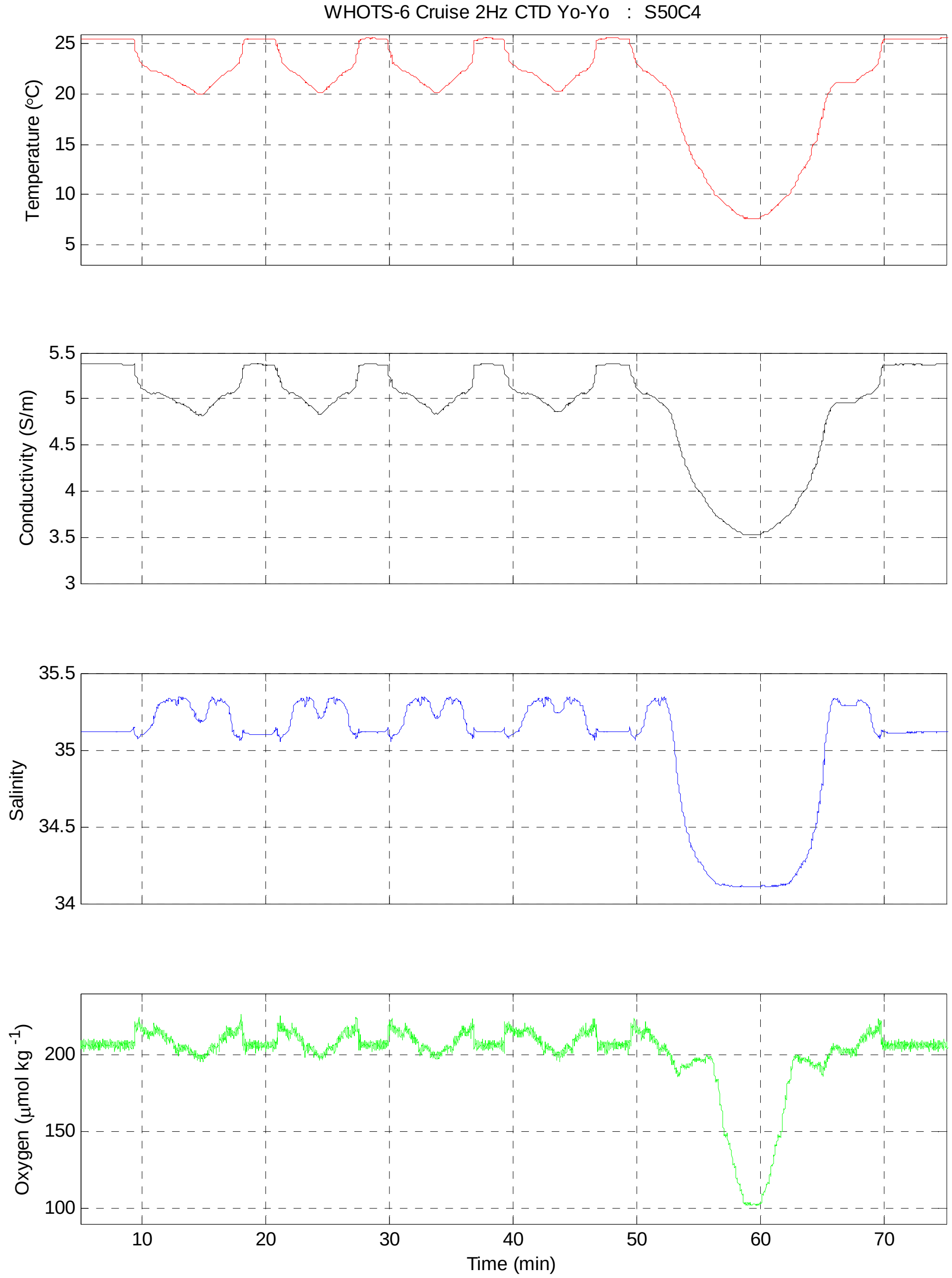

Figure B17. Time-series of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S50C4.

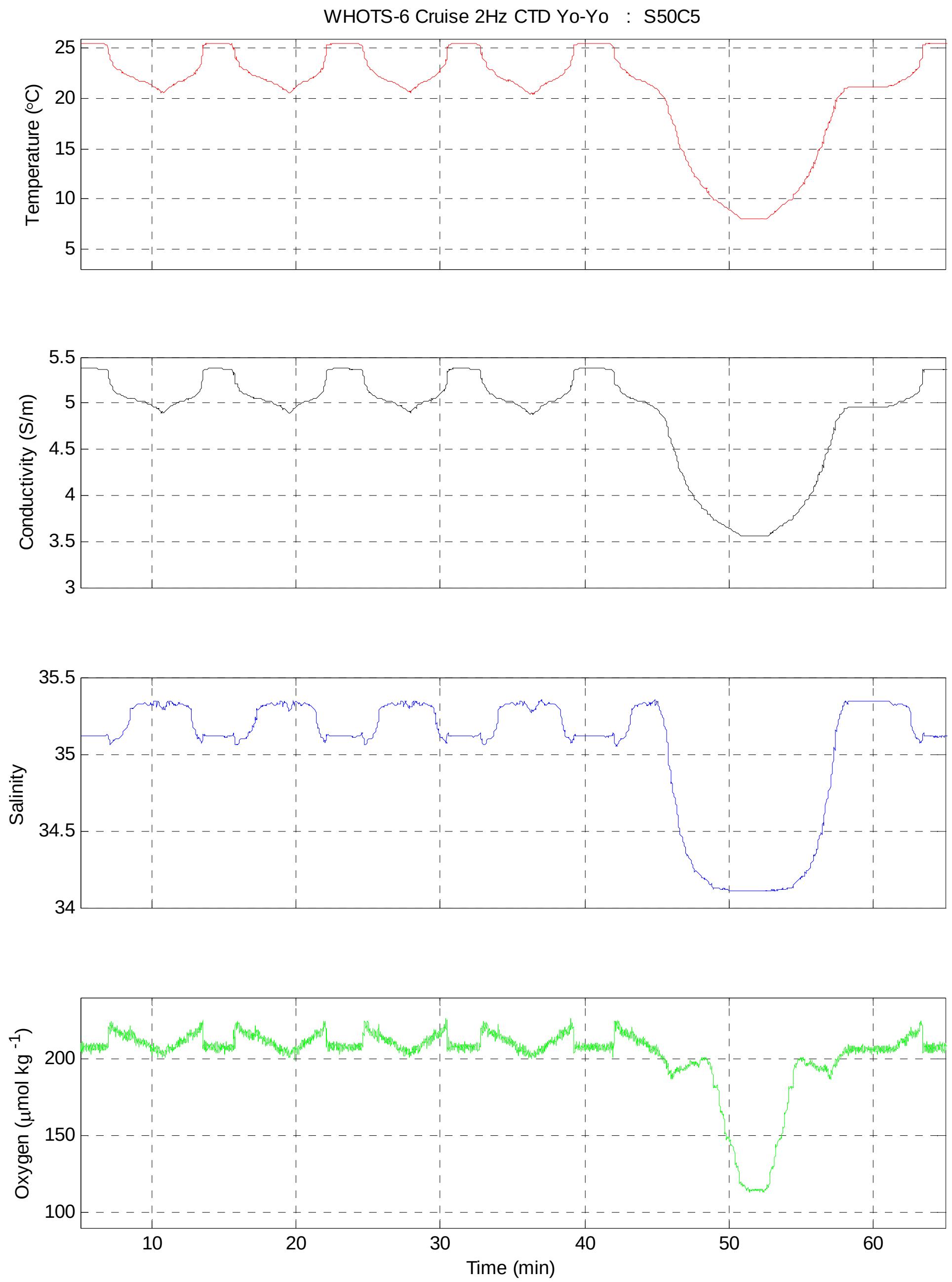

Figure B18. Time-series of 2 Hz temperature, conductivity, salinity, and oxygen data during CTD S50C5.

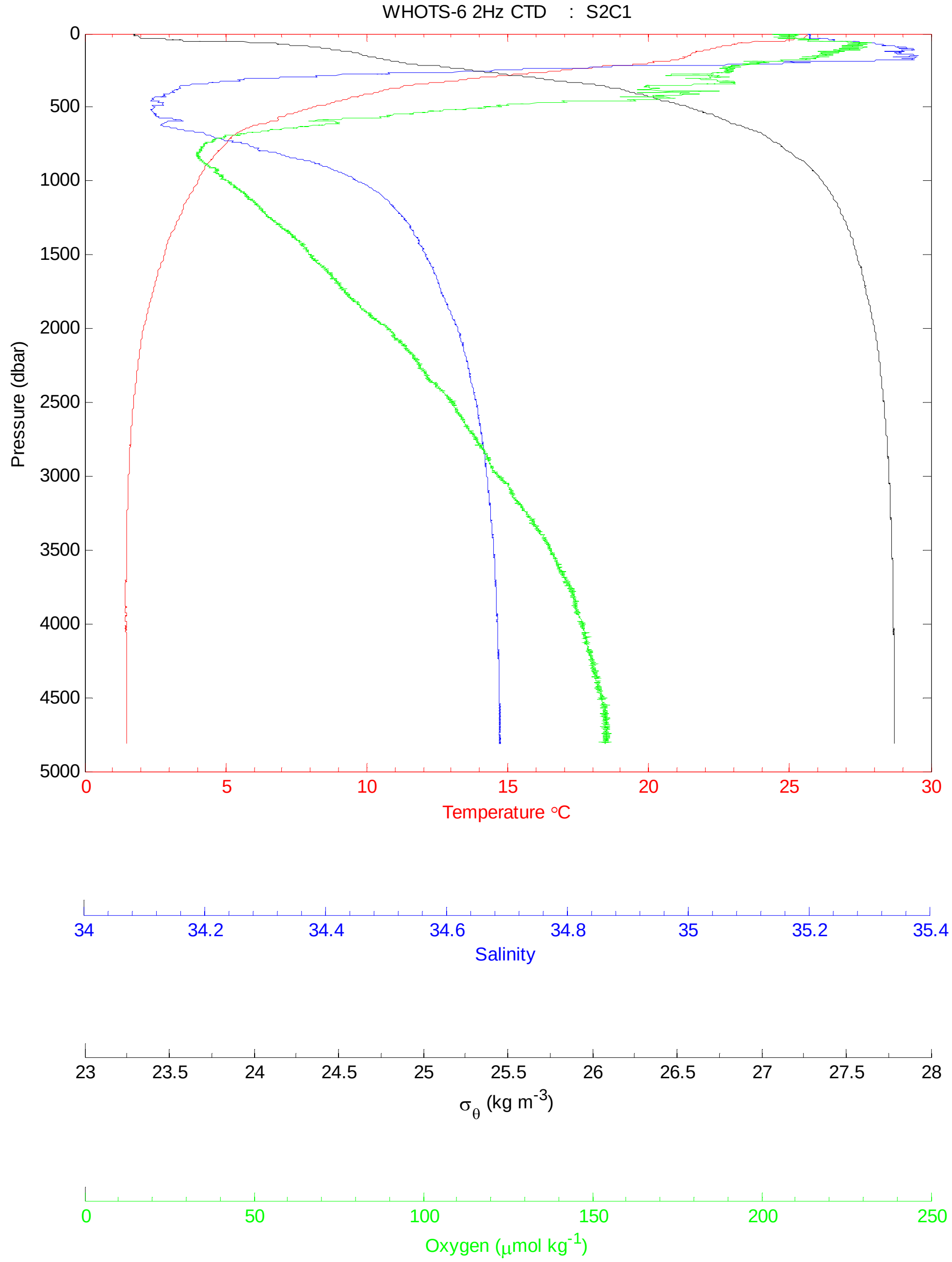

Figure B19. Profiles of 2 Hz temperature, salinity, sigma-theta and dissolved oxygen data plotted against pressure during CTD S2C1.

Appendix C. Thermosalinograph Figures

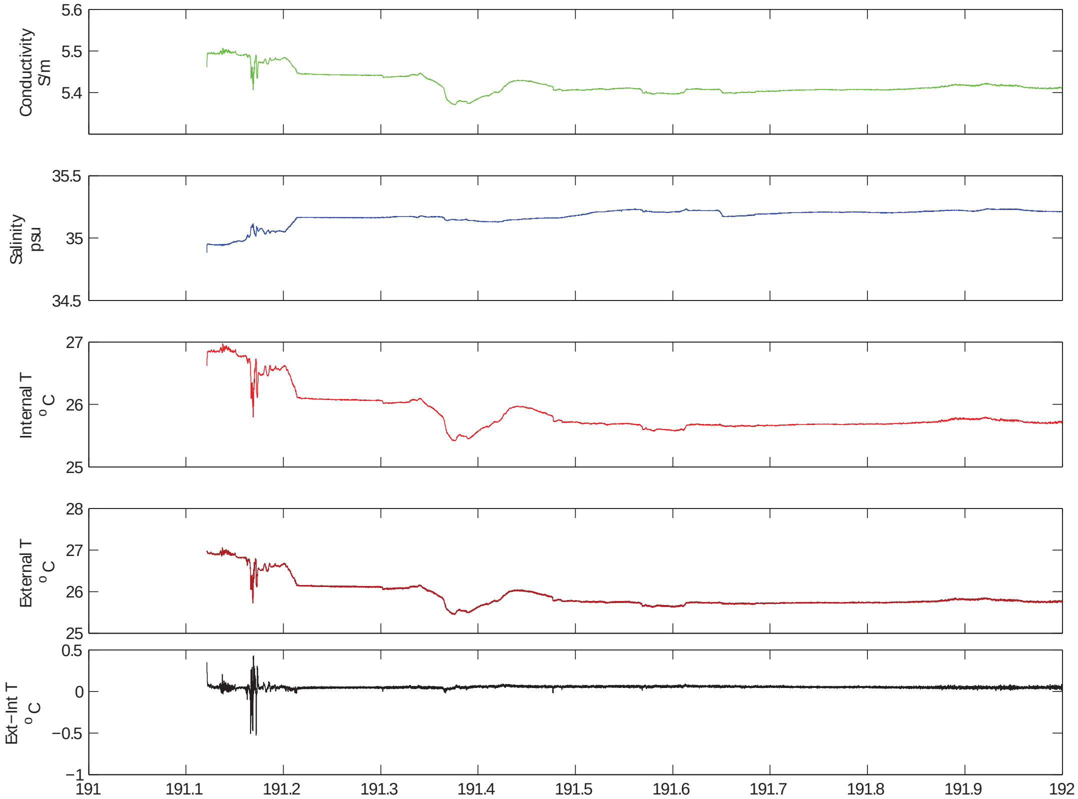

Figure C1. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 10 July 2009. The time axis is in Julian days.

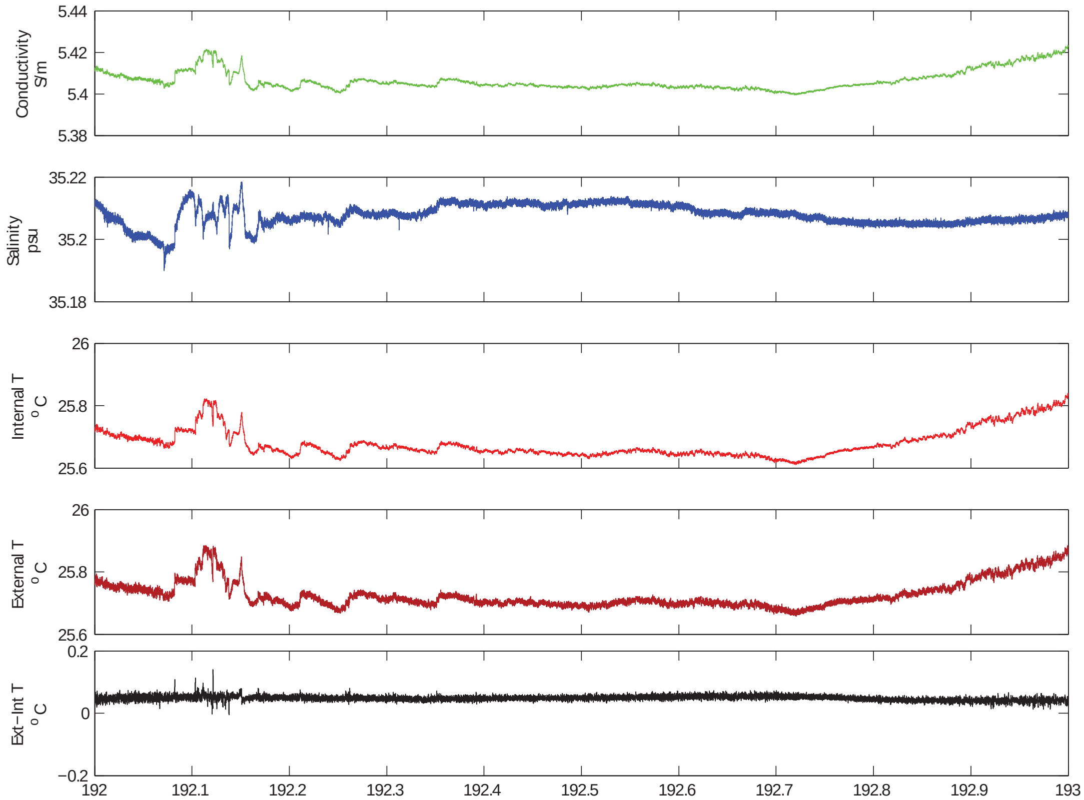

Figure C2. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 11 July 2009. The time axis is in Julian days.

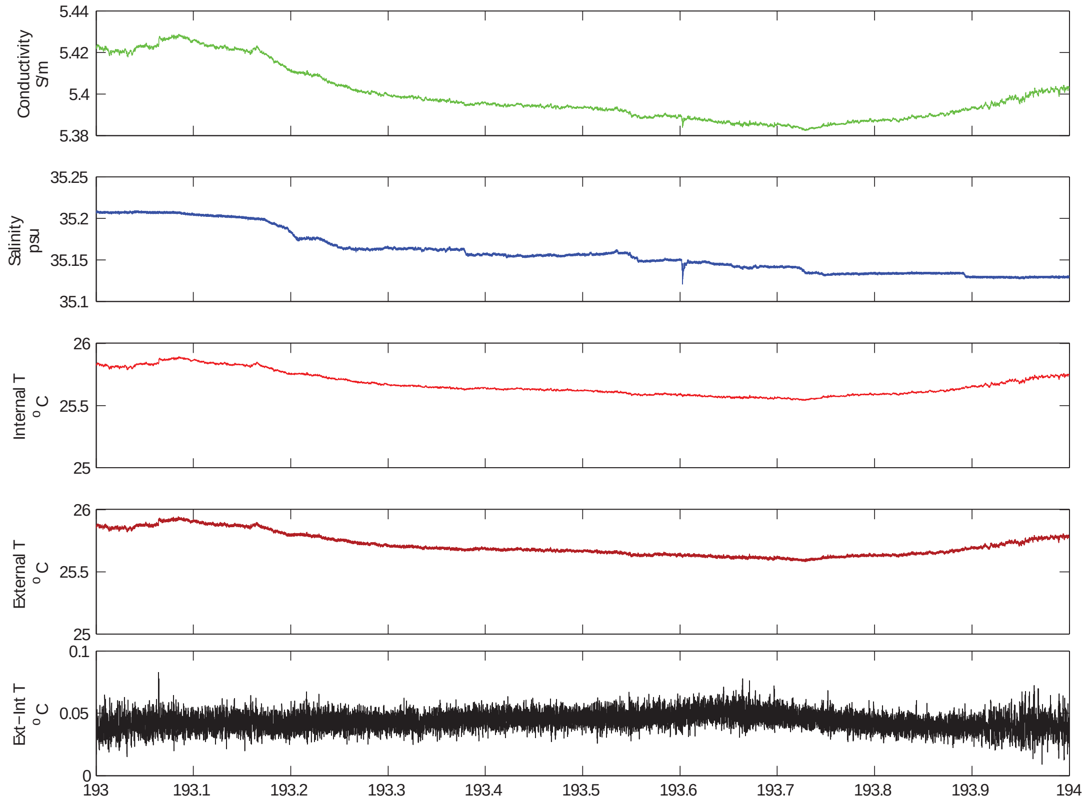

Figure C3. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 12 July 2009. The time axis is in Julian days.

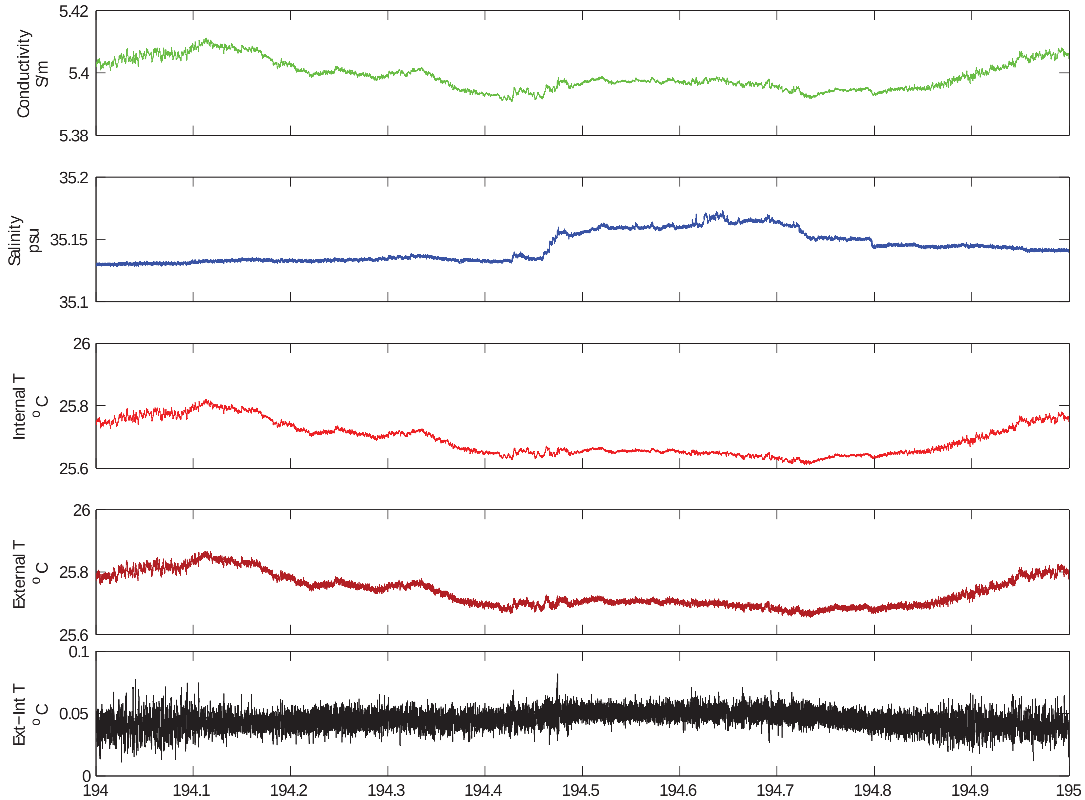

Figure C4. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 13 July 2009. The time axis is in Julian days.

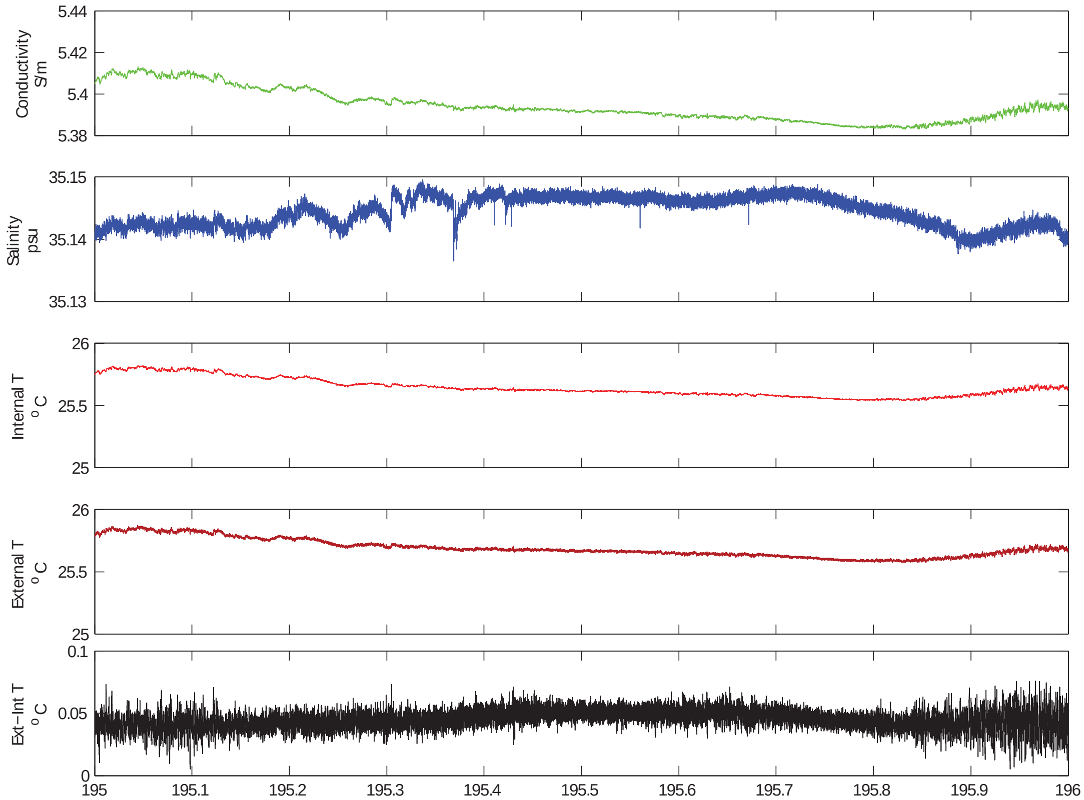

Figure C5. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 14 July 2009. The time axis is in Julian days.

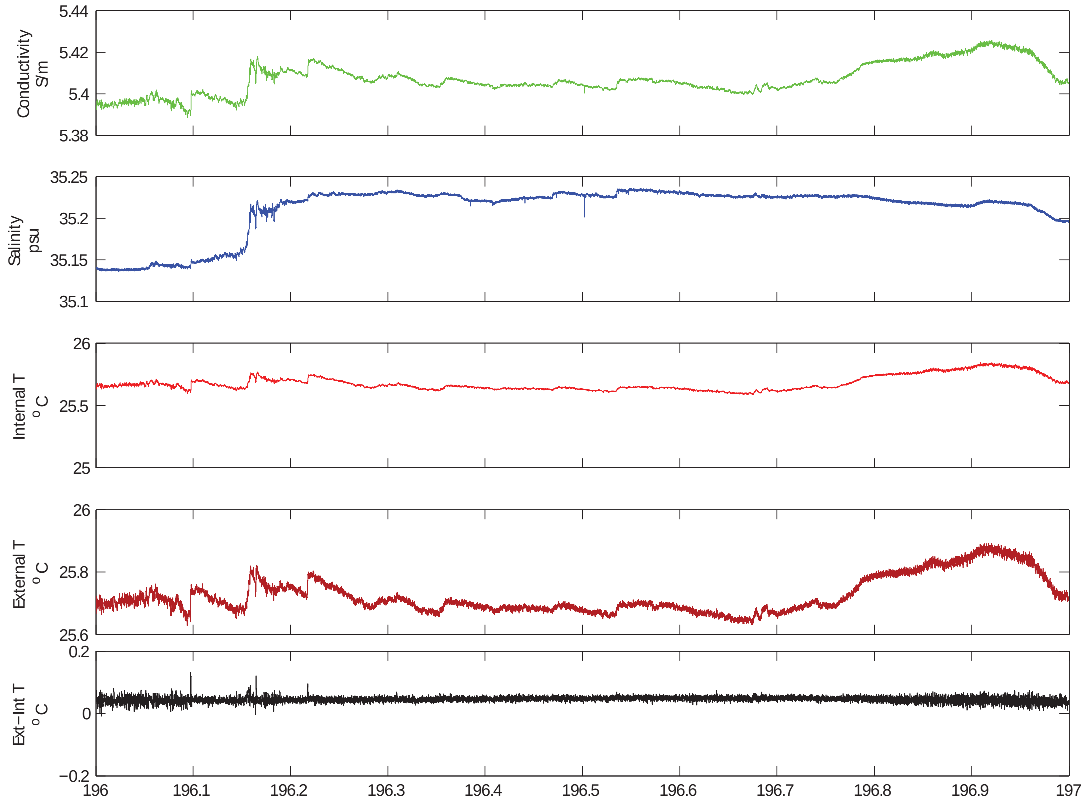

Figure C6. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 15 July 2009. The time axis is in Julian days.

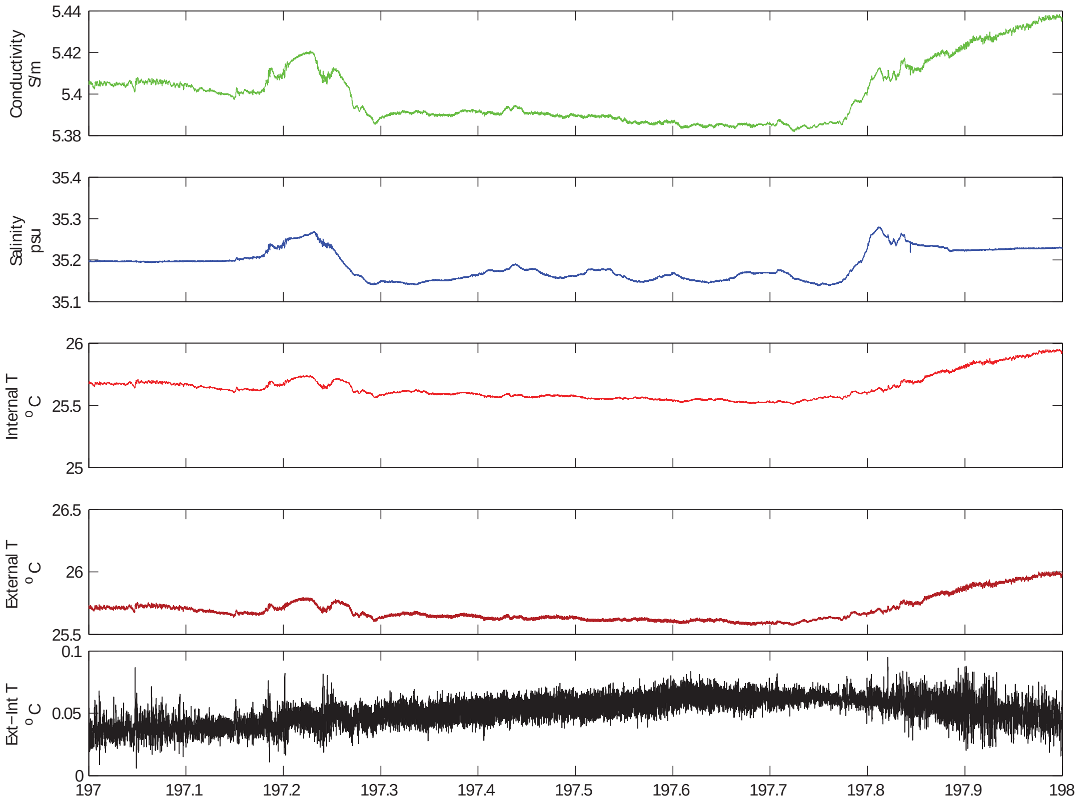

Figure C7. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 16 July 2009. The time axis is in Julian days.

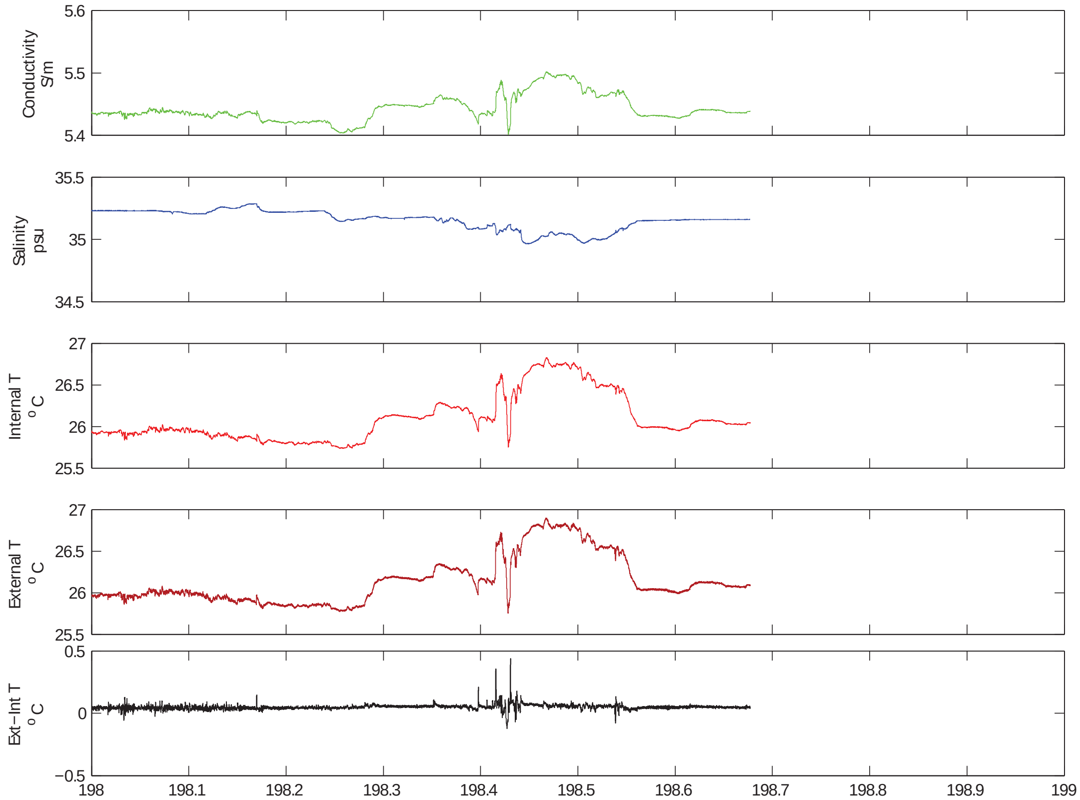

Figure C8. Time-series plots of thermosalinograph conductivity, salinity, internal sensor temperature, remote sensor temperature, and remote - internal temperature difference data during 17 July 2009. The time axis is in Julian days.

Appendix D: WHOTS 2009 Science Party

WHOTS-6 Science Party			
Last	**First**	**Position**	**Affiliation**
Plueddemann	Al	Chief Scientist	WHOI
Whelan	Sean	Technician	WHOI
Ryder	James	Technician	WHOI
Bradley	Frank	Scientist	CSIRO
Lukas	Roger	Scientist	U. Hawaii
Santiago	Fernando	Technician	U. Hawaii
Lethaby	Paul	Technician	U. Hawaii
Snyder	Jefrey	Technician	U. Hawaii
Kelly	Julie	Student	U. Hawaii
Dunn	Thomas	Student	U. Hawaii
Hawkins	Ian	Student	U. Hawaii
Simmons	Bradley	Student	U. Hawaii
Stein	Karl	Student	U. Hawaii
Quisenberry	Carly	Volunteer	U. Hawaii
Bariteau	Ludovic	Scientist	CIRES/U Colorado
Rapp	Anita	Student	CIRES/U Colorado
Stanitski	Diane	Outreach	NOAA Teacher in the Lab / ESRL
Sperber	Scott	Outreach	Teacher at Sea

Appendix E: Sand Island Port Contacts

University of Hawaii Marine Center
1 Sand Island Access Road, Honolulu, HI 96819
Phone (808) 842-9813, Fax (808) 842-9833 Toll Free 1-888-800-0460
email snug@soest.hawaii.edu

Stan Winslow, Marine Superintendent (808) 842-9814
Gen Pickering, Administrative Assistant (808) 842-9810
Grey Drewry , Port Operations Manager (808) 842-9815
John Nikola, Port Engineer (808) 842-9816
Keith Adams, Purchasing Agent (808) 842-9811
Alton Goo, Section Head (808) 842-9812
Keith Yamasaki, Superstructure Design/Fabrication Supervisor (808) 842-9812

Phone numbers for ships while in port
R/V *KILO MOANA* (808) 842-9817 / 842-9834

Appendix F WHOTS 5 Mooring Log complete:

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS 5 MOORED STATION NO. 1198

Launch (anchor over)

Date (day-mon-yr) 5 June 08 Time 03:24:39 UTC

Latitude (N/S, deg-min) 22° 46.085' N Longitude (E/W, deg-min) 157° 53.833 W

Deployed by Ryder / Whelan / Weller Recorder/Observer Lukas

Ship and Cruise No. Kilo Moana 08-08 Intended Duration 365 days

Depth Recorder Reading ~~4704~~ 4702 m Correction Source XBT correction for sound spd plus transducer depth included

Depth Correction — m

Corrected Water Depth 4702 m Magnetic Variation (E/W) ______

Argos Platform ID No. see pg 2 Additional Argos Info on pages 2 and 3

Surveyed Anchor Position

Lat (N/S) 22° 46.0640' N Long. (E/W) 157° 54.0845' W

Acoustic Release Model ORE / Edgetech tandem

Release No. ~~31316~~ 32478 / ~~30841~~ 30841 Tested to 1500 / 1500 m

Receiver No. / ~~32478~~ Release Command ~~147775~~ 132043 / 151241

Enable ~~171161~~ 114442 / ~~114442~~ ~~166312~~ 166312 Disable ~~171510~~ 114461 / 166331

Interrogate Freq. 11 kHz (both) Reply Freq. 12 kHz (both)

Recovery (release fired)

Date (day-mon-yr) 15-Jul-09 Time 1651 UTC

Latitude (N/S, deg-min) 22° 45.849 Longitude (E/W, deg-min) 157 54.406

Recovered by Ryder/Whelan Recorder/Observer Plueddemann

Ship and Cruise No. KM-09-16 Actual duration ______ days

Distance from actual waterline to buoy deck 65 cm m

1

Moored Station Number 1198

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
46	2000	7/8 nylon	7/8					2029	
47	100	nylon	1"	2340	end of nylon			2026	
48	1500	polyprop.	1 1/8"	0052				1912	
49		glass balls	80 balls	0128	on 1/2" trawler chain			1823	卌 卌 卌 卌
50	5	chain	1/2"	0251					
51	1	dual acoustic releases ~~Samson nylon~~		0251	32478/30841 ✓			1833	
52	1	chain	1/2	0251	release links				
53	5	chain	1/2"						
54	20	samson	1"						
55	5	chain	1/2"						
56		anchor	9300 lb	0324:39	22° 46.005N 157°53.833°W				
57									
58		0400,	0403, 0405,	0420	balls implode				
59		4100,	4300, 4500,	bottom	estimated depths of implosion				
60									
61		approx. 10 balls imploded on recovery							
62									
63									
64									
65									
66									
67									

Surface Components

Buoy Type Foamhull MOB Color(s) Hull yellow/white Tower white

Buoy Markings 'B' If found adrift contact University of Hawaii 808 956 7896

Surface Instrumentation

Item	ID #	Height*	Comments
ASIMET	Logger 09		System 1
HRH	227	223.5	
BPR	505	233	
WND	228	260.5	
PRC	214	246	
LWR	205	285	
SWR	208	285	
SST	1419	-156	
PTT	27356, 27364, 27413		
ASIMET	Logger-10		System 2
HRH	216	223.5	
BPR	506	233	Horizontal
WND	205	260.5	wnd wnd 123
PRC	210	246	lwr lwr 24
LWR	210	285	swr swr 24
SWR	207	285	prc prc 150
SST	1306	-156	bpr bpr 59
PTT	1561, 27415, 27416		hrh hrh 256
SIS Argos			
Floater SST	39 SBE	0	SN 1447
Fixed hull SST	1450	-115	SN 10986
pCO_2		-100	
GPS	67699		

*Height above buoy deck in centimeters

2 Xeos —9060

Subsurface Instrumentation on Buoy and Bridle

Item	ID #	Depth†	Comments
SBE37	1419	156	Logger 9
SBE37	1306	156	Logger 10
			initial deployment –
			Argos overplots look
			good with WHOTS 4
			and ship except one
			WHOTS 5 wind looks
			~30° out
		buoy	waterline – 68 cm
		~ 0100 UTC	6/10/08
			small boat ride –
			replace WHOTS 5 lgr9
			wind SN 228 with
			wind SN 219

†Depth below buoy deck in centimeters

Moored Station Number 1198

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back 7/16	Notes
1		buoy hull		1950	quick release + strap Rightside slipped through post windvane			0109	1924 PCO2 floater free
2	7.75	chain	3/4						SST float appears
3		VMCM	03 ✓	1905	spin @ 1903		10	0128	stuck @ bottom
4	2.82	chain	3/4						SST float stuck on recovery
5		seacat	1699 ✓	1902			15	0130	→ line in both props
6	8.68	chain	3/4						1 upper prop, 1 lower prop broken off
7		seacat	1085 ✓	1858			25	0139	synthetic fishing line wrapped
8	3.28	chain	3/4						on load bar
9		VMCM	037 ✓	1853	spin @ 1850		30	0140	line wrapped on both
10	2.92	chain	3/4						props, 1 lower prop broken off
11		seacat	1687 ✓	1849			35	0144	line wrapped on load
12	3.66	chain	3/4						bar
13		microcat	3381 ✓	1845			40	0147	
14	3.66	chain	3/4						
15		microcat	4663 ✓	1841			45	0150 ~~0036~~	
16	1.20	chain	3/4						
17		RDI 1.2 mHz	2530 ✓	1841			47.5	0036	
18	1.00	chain	3/4						
✓ 19		seacat	1088 ✓	1836	slightly banged stern		50	0032	
20	3.66	chain	3/4						
21		seacat	1090 ✓	2004			55	0028	
22	8.70	wire	7/16			7221-3			

Item No.	Length (m)	Item	Inst No. (1092)	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23		Seacat	1092 ✓	2009			65	0023	
24	8.70	wire	7/16			7221-7		0020	
25		seacat	1095 ✓	2013			75	0020	
26	8.70	wire	7/16			7221-5		0013	
27		microcat	4699 ✓	2016			85	0013	
28	8.70	wire	7/16			7221-8		0008	
29		Seacat	1097 ✓	2019			95	0008	
30	8.70	wire	7/16			7221-4		0005	
31		microcat	2769 ✓	2024			105	0005	
32	13.6	wire	7/16			7221-2		0001	
33		microcat	4701 ✓	2027			120	0001	7/16
34	3.66	chain	3/4					2358	7/15
35		RDI 300 kHz	7637 ✓	2031			125	2358	
36	8.70	wire	7/16			7221-6		2353	
37		Seacat	1100 ✓	2035			135	2353	
38	18.75	wire	7/16			7221-1		2348	
39		microcat	4700 ✓	2038			155	2347	
40	250	wire	3/8 ✓	2047		7045-12		2337	
41	500	wire	3/8 ✓	2108		7221-11		2319	
42	500	wire	3/8	2141		7045-11		2259	
43	500	wire	3/8	2204		7212-4		2244	
44	100m	wire	3/8	2209	one piece,	7045-13		2240	termination in excellent
45	200m	nylon	7/8	2229	wrapped termination			2233	condition

Appendix G WHOTS 6 Mooring Log

Moored Station Log

(fill out log with black ball point pen only)

ARRAY NAME AND NO. WHOTS-6 MOORED STATION NO. 1209

Launch (anchor over)

Date (day-mon-yr) 11-07-2009 Time 01:18:48 UTC

Latitude (N/S, deg-min) 22 39.944 Longitude (E/W, deg-min) 157° 56.771

Deployed by Ryder/Whelan Recorder/Observer Pluedemann

Ship and Cruise No. Kilo Moana KM-09-16 Intended Duration 12 mo

Depth Recorder Reading — m Correction Source soundspeed profile

Depth Correction — m

Corrected Water Depth 4758 m Magnetic Variation (E/W) ____

Argos Platform ID No. see pg 2 Additional Argos Info on pages 2 and 3

Surveyed Anchor Position

Lat (N/S) 22° 39.989' Long. (E/W) 157° 56.961'

Acoustic Release Model EG&G 8242, dual

Release No. 31271 / 30847 Tested to 1500 m

Receiver No. ____ Release Command 444214/151411

Enable 460366/166620 Disable 460401/166645

Interrogate Freq. 11 kHz Reply Freq. 12 kHz

Recovery (release fired)

Date (day-mon-yr) ____ Time ____ UTC

Latitude (N/S, deg-min) ____ Longitude (E/W, deg-min) ____

Recovered by ____ Recorder/Observer ____

Ship and Cruise No. ____ Actual duration ____ days

Distance from actual waterline to buoy deck 75 cm ~~m~~

1

6

Moored Station Number 1209

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
46	100	3/8 wire	–	~~9014-13~~	one piece w/	9014-13			
47	200	7/8 nylon	–	2116	wrapped termination				
48	2100	7/8 nylon	–	2127					
49	1500	1" colmega	–	2215					
50		glass balls	–	2325-2358	80 balls on chain				
51	5	1/2' chain	–	7/11/09	(count = 80 balls) ✓				
52	–	release	31271	0053	dual, on				
53	–	release	30847	0053	strongback				
54	5	1/2 chain	–						
55	20	Nystron	–						
56	5	chain	–						
57		Anchor	–	0119					
58									
59									
60									
61									
62									
63									
64									
65									
66									
67									

Surface Components

Buoy Type Foam Hull MOB Color(s) Hull yellow/white Tower white

Buoy Markings "B" IS found adrift contact U. Hawaii 808-956-7896

Surface Instrumentation

Item	ID #	Height*	Comments
ASIMET	L07	logger	System 1
HRH	220	227	
BPR	212	236	
WND	218	267	
PRC	211	247	
LWR	505	278	
SWR	219	275	
SST	1835	-153	
PTT	14637	(WildCat)	ID's 7563, 7581, 7582
ASIMET	L19	logger	system 2
HRH	208	227	
BPR	221	238	
WND	211	267	
PRC	504	247	
LWR	215	278	
SWR	202	275	
SST	1727	-153	
PTT	18136	WildCAT	IDs 14663, 14667, 14697
SIS Argos	25702	buoy hull	
Float SST	717	floating	SBE-39
Fixed SST	14882	-127	RBR-1060
Xeos GPS	611500	250	pwr from well
pCO_2	0019	69	air intake
Lascar	288	198	
Lascar	249	231	

*Height above buoy deck in centimeters

Moored Station Number 1209

7/10/09

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
1		buoy	–	1931			0		
2	7.75	3/4 chain	–						
3		VMCM	010	1840	rotor spin 1834		10		
4	2.82	3/4 chain	–						
5		μCAT	6893	1835			15		
6	3.6	3/4 chain	–						
7		MAVS	10260	1831	sensor down		20		
8	2.8	3/4 chain	–						
9		μCAT	6894	1830			25		
10	3.28	3/4 chain	–						
11		VMCM	058	1825	rotor spin 18:19		30		
12	2.82	3/4 chain	–						
13		μCAT	6895	1824			35		
14	3.66	3/4 chain	–						
15		μCAT	6896	1819			40		
16	3.66	3/4 chain	–						
17		μCAT	6887	1817	w/pressure ✓		45		
18	1.2	3/4 chain	–						
19		ADCP	1825	1948	heads up, ~~1200kHz~~ 600kHz batt case		47.5		
20	0.5	3/4 chain	–						
21	3.66	μCAT	6897	1949	~~w/pressure~~		50		
22		3/4 chain	–						

Item No.	Length (m)	Item	Inst No.	Time Over	Notes	Data No.	Depth (m)	Time Back	Notes
23		μCAT	6898	1953	~~w/pressure~~ bumped on deck		55		
24	8.7	7/16 wire	—			9014-5			
25		μCAT	6899	1959	~~w/pressure~~		65		
26	8.7	7/16 wire	—			9014-4			
27		μCAT	3618	2003	~~w/press~~		75		
28	8.7	7/16 wire	—			9014-6			
29		μCAT	6888	2006	w/press ✓		85		
30	8.7	7/16 wire	—			9014-7			
31		μCAT	3617	2009	~~w/press~~		95		
32	8.7	7/16 wire	—			9014-3			
33		μCAT	6889	2012	w/press ✓		105		
34	13.6	7/16 wire	—			9014-2			
35		μCAT	6890	2016	w/press ✓		120		
36	3.66	3/4 chain	—			~~9014-8~~			
37		ADCP	4891	2019	batt case 3169 beams up, 300 kHz		125		
38	8.7	7/16 wire	—			9014-8			
39		μCAT	3634	2023	~~w/press~~		135		
40	18.75	7/16 wire	—			9014-1			
41		μCAT	6891	2027	w/press ✓		155		
42	250	3/8 wire	—	2027		7221-12			
43	500	3/8 wire	—	2035		7212-3			
44	500	3/8 wire	—	2048		9014-11			
45	500	3/8 wire	—	2059		9014-9			